Regional Economic Development from a Local Economic Perspective
– A General Accounting and Modelling Approach

by

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Udvikling i den lokale økonomi set i et regnskabs- og modelleringsperspektiv

af

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Contents

Indholdsfortegnelse

Section 1:

Summary

1. Summary

1. Introduction and background

The primary results of the doctoral dissertation are presented in the summary. The summary also includes an outline of the preliminary work for each section of the doctoral dissertation.

The doctoral dissertation comprises four main sections. ***Main Section A*** summarises analyses of regional and local development in Denmark from 1980 onwards (Sections 2 and 3 of the study). ***Section 2*** contains an empirical description of trends in the geographical agglomeration or dispersion of economic activity (concentration versus deconcentration) and trends involving changes in average income differences (convergence versus divergence). The results of regional economy projections (concentration and deconcentration) using an aggregated modelling system for Denmark's regional and local economy[1] are presented. ***Section 3*** includes a decomposition of the economic trends (concentration and deconcentration, respectively) into explanatory factors. The local-economy LINE model is used in the decomposition of the regional economic development, and fundamental, methodological issues relating to the decomposition are presented.

The general interregional model is presented in ***Main Section B***. In this context, "general" means that the model is based upon the general dimensions of local economies, both geographical (place of production, place of residence, factor market and commodity market) and technical (sectors, factors of production, types of household and commodities). These dimensions apply to all local areas included in a market economy and the structure after the local economy is described by the two-by-two-by-two principle. ***Section 4*** presents the general interregional quantity model, which identifies the level of economic activity in a local area, i.e. production, income, employment, etc., and the level of interaction among the local areas, i.e. trade, commuting, shopping, tourism, etc. The section also presents the quantity model's solution. The structure of the general interregional quantity model is used as a point of departure for classifying local economies in terms of their local economic functions. ***Section 5*** presents the general interregional price model. The price model includes an identification of costs, prices and nominal incomes in local areas. The section also presents the model's solution, and the structure of the general interregional price model is used as a point of departure for classifying local areas' economies in terms of their competitiveness. The section ends with a presentation of an overall simultaneous solution of the quantity and price model, which assumes a single link between export prices (the price model) and export volumes (the quantity model). In ***Section 6***, the general interregional quantity and price models are reformulated to illustrate the significance of demographic changes to the local economy – especially the rising percentage of elderly in the population of developed countries. To examine the significance of aging to the structure of production, demand, income and employment, the general interregional quantity and price model is reformulated into changes. The two sub-models are solved analytically, and the way in which local economies adapt in the short, medium and long term is explained. ***Section 7*** presents LINE, a local economic model for Denmark's municipalities. The structure of LINE largely follows the general interregional model, but differs in specific areas which reflect the data processing possibilities and the need for reflecting the subdivision of decision makers who are part of a local economy. Ten different applications of LINE are presented. Each version of LINE is con-

[1] The modelling system comprises a model for the international economy (the GTAP Model), a national model for Denmark's economy (AAGE Model), a regional model for agricultural production (ESMERALDA) and an interregional model for Danish municipalities (LINE).

figured differently, i.e. the geographic aggregation is different (county model, municipal model, catchment-area model, sub-municipal model) and the sector-based aggregation is different (tourism model, food industry model, transportation industry model, public-sector model, etc.), commodities (within tourism, food consumption, transportation, the governmental consumption, etc.), types of labour (classified by gender, age, education, etc.) and types of households (married/unmarried, children/childless, etc.). ***Section 8*** presents an analysis of the regional consequences of introducing road pricing in Denmark. The analysis uses LINE and describes how LINE is included in a complete system of models: an international general equilibrium model for modelling international economic trends (GTAP), a national general equilibrium model for modelling the Danish economy (AAGE), an interregional general equilibrium model for the local economy (LINE), and a national transportation model (Landstrafikmodellen).

Next, ***Main Section C*** is concerned with data for local economies, particularly the issue of establishing local national accounts. ***Section 9*** presents a three-dimensional approach (termed the two-by-two-by-two principle) as the point of departure for recording data concerning local economic activity. The conversion of this principle into a local social accounting matrix (SAM) for local areas/municipalities in Denmark is described. Data sources and specific methods for setting up and estimating a SAM for a local economy are presented. ***Section 10*** presents a system of commodity balances and regional commodity flows for local economies, including how they are estimated and their level of aggregation. The section explains why commodities should be introduced into local social accounting matrices and why calculative detailing and accounting restrictions should be used in the estimation of local social accounting matrices to ensure a high level of data quality.

Various model-based analyses of the regional consequences of infrastructure projects and regulation are presented in ***main section D***. ***Section 11*** analyses the regional consequences of establishing a fixed link across Denmark's Great Belt. The analysis uses AIDA, an interregional quantity model for Denmark. The effects of infrastructural improvements are modelled by applying elasticities for transportation costs and, thus, the significance of commodity prices for the regions' competitiveness and trade structure. Based upon export changes and modified trade coefficients, the significance of the Great Belt Link for regional production, income and employment and for the regional trade structure is modelled in AIDA. ***Section 12*** analyses the regional consequences of a fixed link across the Fehmarn Belt. The analysis includes the impacts of a changeover from ferry operation to a fixed link and how this will affect regional competitiveness, employment and income, i.e. the significance for employment and income of a changeover of traffic routes to the Fehmarn Belt corridor from the other corridors linking the Baltic Sea Region, Scandinavia and the European mainland. An "eclectic method" is applied to expand the analysis and include new effects and summarises the broader effects of a fixed link across the Fehmarn Belt based on a combination of different modelling approaches. In ***Section 8*** a LINE-based analysis presents the effects of making transit across the Great Belt Link free of charge. The analysis calculates the implications of less expensive transportation costs on commodity prices in terms of interregional trade, shopping and tourism and the implications of declining commuting costs on income. The changes in costs, and thus in prices, are further calculated in the price model in LINE, to specify the overall price changes broken down by region, commodity categories, business, etc. Thus, cost and price changes are not exogenously fixed as in AIDA (the first analysis of the Great Belt Link), but endogenously determined using the price formation model in LINE. At the same time, a fully developed interaction is included, i.e. interregional and international trade, shopping and tourism, while commuting is included in the domestic section only. The calculations also compute the effects of financing free transit across the Great Belt Link through taxation.

In ***Section 13*** LINE is used for making an extended analysis of the consequences of providing free transit across the Great Belt Link. In addition to the cost and pricing effects described, cf. ***Section 8*** of the study, the externality effects of reduced travelling costs on income are also included. First of all, econometric analyses[2] show that the higher the commuting costs, the higher the income. If crossing the Great Belt Link were to become free, nominal incomes and prices would fall, which would lead to rising exports and declining imports. Secondly, the econometric analyses show that the lower the cost of transportation to the large urban centres (Copenhagen, Århus, Odense and Aalborg), the higher the income per person (productivity) employed. These direct and derived positive income effects from an improved transportation system are also included in the calculations, so that exports grows and imports decline in regions benefiting from free transportation across the Great Belt. In ***Section 14*** the significance of teleworking for a regional economy is analysed. A model for correlating the degree of teleworking and productivity is included in the LINE calculations[3]. In ***Section 15*** the consequences for tourism activities of free of charge of the Great Belt Link are examined.

[2] The econometric analysis was performed by Morten Larsen.
[3] The econometric analysis was performed by Arne Risa Hole.

A. Regional and Local Development in Denmark

2. Regional Development Trends in Denmark[4]

Section 2 summarises the regional and local economic development trends in Denmark presented in Madsen & Andersen (2003). As regards living condition trends, Denmark has been experiencing convergence (i.e. the differences in average income have been declining) for a very long period, from the end of World War II until the mid 1990s (Dilling-Hansen et al. 1997; Groes 1997; Expert Committee 1998[5], Jensen-Butler et al. 2002; Madsen & Andersen 2003; and Jensen-Butler & Madsen 2005). Since the mid 1990s, the average income spread has remained unchanged or widened slightly. As something new, Madsen & Andersen point out that the result depends on whether the focus is on average primary income, i.e. income before tax and transfer payments – which has tended towards divergence – or whether the focus is on the average disposable income, i.e. income after tax and transfer payments, where the spread has remained virtually unchanged (Madsen & Andersen 2003; Jensen-Butler & Madsen 2005). Another new aspect pointed out by Madsen & Andersen is the importance of the welfare state's function in the regional redistribution of income.

Madsen & Andersen include the issue of the dispersion of economic activity where – as regards the "large regions" or commuter catchment areas – there has been a clear trend towards deconcentration or a spread of economic activity up to 1990, while concentration has prevailed since 1990 (Madsen & Andersen 2003; Pedersen 2005). Up to 1990, the trend was influenced by the relocation of economic activity from Greater Copenhagen to Jutland. Concentration has prevailed since 1990, where the level of growth in Greater Copenhagen has been significantly greater than in the other regions. This appears first in population trends and later in primary income and disposable income trends.

The spread within commuter catchment areas has shown a tendency towards deconcentration throughout the period. This reflects the high level of relocation out of and into the urban centres within Copenhagen, Århus and other urban areas noted throughout the period. Distribution targets are set for population and income density, both between commuter catchment areas and within commuter catchment areas – which has never been done before in Denmark's regional research.

In ***Section 2*** the results of regional-economy projections up to 2015 (concentration and deconcentration) and the results of several different scenario analyses are summarised:

[4] Section 2: Bjarne Madsen and Anne Kaag Andersen (2003): *Regional Development Trends in Denmark*. Paper presented at a seminar at the Ministry of the Interior and Health, 29 January 2003.
[5] Bjarne Madsen served as secretary for the Expert Committee and performed a substantial number of the report's calculations.

Table 1. Consequences for local income: Baseline, market-specific scenarios and policy-regulated scenarios

	Greater Copenhagen and major cities	Smaller towns and sub-urban areas in Greater Copenhagen and major cities	Rural municipalities	Agricultural municipalities	Outlying municipalities	Vulnerable municipalities I	Vulnerable municipalities II
Basic scenario	+	++	+/0	-	-	--	--
Market-decided scenarios:							
Liberal. scenario	+	++	+/0	--	--	-	-
Industry	0	++	0	-	-	--	--
Tourism	+	0	-	-	0	(++)	(+)
Political control:							
Welfare scenario	0	+	++	-	0	--	--
Recreational /demographic	+	+	0	-	-	--	--
Environmental scenarios	+	+	0	-	--	-	-

The projection, the first of its kind in Denmark carried out for municipalities[6], shows that economic progress particularly occurs in areas typified by the production of advanced industrial products and services[7], while weaker economic growth is to be expected in areas with conventional industrial production and the production of agricultural products[8] [9]. The projection was performed using a modelling system (in Hasler et al. 2002; Madsen et al. 2007), set up together with the Institute of Food and Resource Economics at the University of Copenhagen, comprising a model for international economy (GTAP), a national model for the Danish economy (AAGE), a regional model for agricultural production (ESMERALDA), and an interregional model for Danish municipalities (LINE).

The projection is one of a series of regional model projections. Madsen et al. (1992) made projections using AIDA, an interregional model for Denmark with counties as a geographical unit[10] (Madsen et al. 1992). The projection indicated concentration (strong growth in income and employment) in the municipalities of Copenhagen and Frederiksberg), average growth in the traditional industrial counties of Jutland, whereas outlying counties such as Storstrøm and Bornholm showed sharp economic decline. This was the first indication of the potential for pronounced growth in Greater Copenhagen after the long period of decline in the 1980s. An alternative scenario, which incorporated a trend equivalent to a continuation of the favourable

[6] In an international context, this is a unique modelling development and utilisation in terms of the model’s geographic specification, complexity and theoretical base.

[7] “Greater Copenhagen and large urban areas” and “Small towns and catchment areas for Greater Copenhagen and large urban areas” are marked with “+” and “++”, respectively.

[8] Rural municipalities and Outlying municipalities are marked with “-”, while Vulnerable municipalities and Disadvantaged municipalities are marked with “--”.

[9] The projection shows the quantitative growth, i.e. the effect toward concentration or deconcentration, respectively.

[10] The first presentation in Denmark using an interregional model for making projections for all counties.

developments experienced by Jutland's industrial counties in the 1970s and 1980s, indicated deconcentration, i.e. a far more favourable trend for the counties of Jutland.

Projection efforts have continued and, from 2005 onward, LINE-based projections are continually being performed on the basis of the national projections using ADAM (Dam 1995). These projections focus on labour-market trends. The projections were performed at the municipal level for East Denmark (Lundtorp et al. 2005; Madsen & Lundtorp 2006), for new municipalities (Christoffersen et al. 2006 and 2007) and are broken down by factors such as gender, age and education. The projections indicate a higher concentration of jobs, both between and within commuter catchment areas. Job trends show relatively strong growth in the centre of Copenhagen and the outer commuter areas, while weaker growth is projected for commuter areas near the centre of Copenhagen. Calculated in terms of the population's place of residence, the projection shows concentration between commuter catchment areas and deconcentration within the areas. This is caused by an increasing distance of the individual commute. At the same time, the trend also indicates a growing demand for labour with higher education, particularly within health and education.

The scenario analyses (see Table 1) are grouped by "market driven scenarios" and "policy-based scenarios". Under "market driven scenarios", the study examined agricultural policy, primarily determined by food-demand trends and by agreements involving the EU, the US and other countries under the auspices of the WTO (Hasler et al. 2002). This trend could ultimately lead to complete deregulation, which is an assumption of the *deregulation scenario*. In recent years, significant changes have been made to Europe's Common Agricultural Policy (CAP), i.e. the then Agenda 2000 reform. In spite of the fact that the changes made at that time were quite extensive since the commencement of the deregulation process in 1992, considerable direct support to land and livestock was still granted, and, to a lesser extent, to direct environmental and rural development aid. Europe was under pressure to completely or partly phase out the CAP subsidies and was supported at the time by the expected enlargement of the EU to the east and by consumers' flagging willingness to finance an extremely large agricultural budget. The deregulation scenario examined the consequences for regional production, income and employment in agriculture, the food industry and other business sectors by changing in food prices to the world-market level, etc.

In addition, industrial trends were examined within the framework of globalisation (Andersen and Christoffersen 2002). The superior ability of rural municipalities to generate progress in labour productivity from 1980–1996 appears to have been lost after the early 1990s together with the shift in economic trends. If it turns out that the peripheral, localised superior productivity of industry cannot be upheld in the long run, this may have decisive implications for regional income and employment development. To illustrate such consequences, a LINE-based model run was performed which assumed that the growth rate of the industrial sectors, particularly characteristic of the peripheral areas of Denmark – i.e. the endangered sectors – was not higher than that of all industrial sectors on the whole over a ten-year period. Even if the model run performed was simply designed, it clearly demonstrates that if the peripherally oriented industrial sectors lose their superior ability to develop productivity and if this becomes a lasting loss, it will cause income and employment trends to shift in the direction of urban areas.

Finally, tourism scenarios are placed under market driven development as they are largely based on the growth of user demand. The results of tourism's significance to production, income and employment are presented and broken down by sector and region. In addition, tourism's effect on employment and primary income, broken down by qualifications, gender, age, disposable income, income tax, transfer payments, and product taxes and trade margins, etc., is studied. An example of scenario analyses for tourism is also presented. The three scenarios include 1) a 20% rise in overnight tourism by foreign tourists on Bornholm; 2) a 20% increase in same day tourism by foreign tourists in Southern Jutland; and, 3) a 20% increase in domestic tourism in Ringkøbing. The detailed results are presented in each scenario as regards tourism's significance to production, income, employment, private consumption, disposable income, transfer payment, income tax, VAT, margin of profit and interregional import and export.

Under "policy-based scenarios", the regional consequences of the Government's financial policies are studied (the "Welfare Scenario", see Dam et al. 1997), recreational initiatives in municipalities and regions (Andersen 2002), as well as environmental scenarios in agricultural policy (Hasler et al. 2002). The Welfare Scenario is used for studying the regional impacts of two scenarios of governmental fiscal policy. In the first scenario, a study is made of the impact of reducing public expenditure, while in the second scenario, a "balanced budget" is reviewed, in which the public-sector savings are offset by a reduction in governmental income taxes. Reducing governmental expenditure leads to declining wages which improves the competitiveness of the export. As export is largely concentrated in the largest industrial towns of Jutland, the benefits of a contractive fiscal policy are particularly noticeable here, while municipalities with many public-sector employees incur losses. If income taxes are reduced at the same time, this will benefit municipalities with high taxable incomes.

The planting of forests is studied under recreational initiatives. To assess the number of people who move into an area because a municipality has more wooded areas, the relocation patterns between Danish municipalities was analysed. The population was classified according to their situation at both the beginning and the end of the process (workforce, student, outside the workforce). In addition, some of the groups were classified according to their level of education. The number of categories is eleven all told. Only one factor in the model is important to all groups, i.e. the distance. The shorter the distance, the greater the likelihood of choosing to move to this destination. The other factors are significant to only some of the groups. Only three of the eleven groups give priority to the percentage of wooded area when deciding where to relocate. The percentage of woodland is increased in the three scenarios which causes a slight increase in the number of people moving into an area. These new inhabitants will generate relatively slight increases in wage income, transfer payments and tax payments into the municipality. The study concludes that planting wooded areas is a way of increasing the attractiveness of an area and attracting a small number of new inhabitants.

The *Environmental Scenario* studies whether the continued growth of environmental regulations can lead to additional tightening of agricultural production as the current environmental regulations do not meet the objectives to the full. Two calculation assumptions are set up: i.e. a general and a differentiated tightening of the so-called harmonisation requirements. The harmonisation requirements regulate the maximum number of livestock allowed in proportion to the area at the farm's disposal. The targeted tightening in the first scenario is calculated by assuming that the reduction of the livestock impact (per hectare) is larger on sandy than clay soil. The particular tightening for farms on sandy soil is justified by the fact that sandy soil has a greater risk of nitrogen leaching than clay soil. The second scenario assumes the same reduction in livestock impact regardless of soil type.

Both subsidiary scenarios assume a 7.4% reduction of livestock production compared to the base process. This reduces the value of the overall agricultural production. The total value of the agricultural production is reduced by about 3%. Not surprisingly, the greatest effects are seen in regions dominated by livestock farming, and the greatest differences between the general and differentiated tightening of the harmonisation requirements are calculated for regions where sandy soil predominates. As expected, the differentiated tightening has the greatest negative impact on the production in these areas. In general, the impact of the harmonisation requirements on Denmark's easternmost regions is relatively small, whereas it has a substantial effect in Jutland. These results are not surprising as the majority of livestock farms are located on sandy soil in the western parts of Denmark.

The analyses review the effects on economic activity, i.e. whether implementation/realisation of a scenario led to concentration or deconcentration.

If, at the same time, various assumptions are set up for collating population, employment and income trends,[11] the effects of the base scenario and the scenarios as regards concentration/deconcentration and convergence/divergence are summarised as follows:

Table 2: Local income consequences: Baseline market-driven scenarios and policy-based scenarios

	Concentration/deconcentration	Convergence/divergence
Base scenario	Concentration	Divergence
Market-driven scenarios:		
Deregulation scenario	Concentration	Divergence
Industry	Concentration	Divergence
Tourism	Deconcentration	Divergence
Policy-based scenarios:		
Welfare scenario	Deconcentration	Convergence/divergence
Recreat./trans.	?	Convergence/divergence
Environ. scenarios	Concentration	Divergence

It is apparent that most of these scenarios will lead to concentration – except for tourism and the welfare scenario. The concentration trend was particularly explained by the negative impact on agriculture and the growth of services and advanced industry. Tourism deconcentration is explained by the fact that tourism benefits the outlying areas, because this is where a significant segment of the tourism – beach tourism in particular – is localised. The welfare scenario led to increased industrial activity resulting from reduced level of public service, which leads to declining wage levels that improve the competitiveness of Danish export, thus benefiting export-oriented industrial areas which are more heavily concentrated in Jutland.

At the same time, it was expected that the base scenario would lead to divergence as the growth was achieved in sectors with high average incomes within services and advanced industry. The scenarios are also expected[12] to lead to divergence, because growth is achieved in sectors with above-average incomes and which are localised in major urban areas. It should be noted that the tourism scenario also led to divergence, because this involves a low-income activity that achieves growth and is largely localised in outlying areas which thus reduces the average income of these areas.

[11] The analyses' results of the effects with regard to "convergence/divergence" are not based on models.
[12] It should be noted that no model-based calculations were made to illustrate the effect on the income spread. Model-based calculations solely illustrated the consequences with regard to concentration and deconcentration.

Projections and scenario analyses are unique in Danish and international contexts alike, both as regard the geographic degree of detail and the degree of detail in the description of the economic activity; also the model's flexibility is quite unusual with regard to aggregation.

3. Decomposition analysis: an extended theoretical foundation and its application to the study of regional income growth in Denmark[13]

It is important for decision makers to know the determinants of regional development. Among the significant factors which politicians can influence, the rationale is that by knowing these determinants politicians can choose and apply the instruments that will influence regional development in a given direction. ***Section 3*** of the study by Jensen-Butler & Madsen (2005) is an attempt to isolate the factors that have had an impact on regional development. LINE, described in detail later in the doctoral dissertation, is used in the decomposition analysis. The model applied is briefly characterised as follows:

[13] Jensen-Butler, Chris and Bjarne Madsen (2005): Decomposition analysis: an extended theoretical foundation and its application to the study of regional income growth in Denmark. *Environment and Planning A.*

$$y_{t_1} - y_{t_0} = M^S_{q,ir}(Pop_{t_1}, Inctran_{t_1}, Taxrate_{t_1}, Othinc_{t_1}, Intcon_{t_1}, Pcsh_{t_1}, Pccomp_{t_1}, Tour_{t_1},$$
$$Govcons_{t_1}, Invest_{t_1}, Import_{t_1}, Export_{t_1}, ComTax_{t_1}, Prices_{t_1}, Labcont_{t_1})$$
$$-M^S_{q,ir}(Pop_{t_0}, Inctran_{t_0}, Taxrate_{t_0}, Othinc_{t_0}, Intcon_{t_0}, Pcsh_{t_0}, Pccomp_{t_0}, Tour_{t_0},$$
$$Govcons_{t_0}, Invest_{t_0}, Import_{t_0}, Export_{t_0}, ComTax_{t_0}, Prices_{t_0}, Labcont_{t_0}) \ldots\ldots\ldots\ldots(1)$$

where:

y: *primary income*

$M^S_{q,ir}$: *LINE, which is an interregional (ir) quantity model (q) on structural form (S)*

Pop: *Population size and composition commuting*

Inctran: *Income transfer*: *Share of recipients and average amount received*

Taxrate: *Tax rates (state, local authorities)*

Othinc: *Other income*

Intcon: *Intermediate consumption coefficients*

Pcsh: *Share of private consumption*

Pccomp: *Composition of local private consumption*

Tour: *Tourist expenditure*

Govcons: *Government consumption*

Invest: *Investment*

Import: *Imports from abroad*

Export: *Exports abroad*

ComTax: *Commodity taxes and trade margins*

Prices: *Prices*

Labcont: *Labour demand coefficients*

t_1, t_0: *Final and start year for decomposition*

The analysis examines the development of primary income (y). The analysis is carried out using a model (M) that is an interregional (ir) quantity model (q) set up in a structural form (S).[14] This model used in this instance is LINE, a quantity model[15] on structural form, i.e. the LINE equations describe the detailed relations without mathematically solving the entire or parts of the model.

The analysis shows that the development of exports abroad, the labour content and the governmental expenditure have special significance for regional development. Although this general result is not directly convertible into operational targets and resources, the analysis underpins the general focus on improving regional competitiveness achieved using other analyses (Heinesen & Groes 1997; Copenhagen Economics & Inside Consulting 2004; Inside Consulting et al. 2005). The important aspect here is that the decomposition analysis includes

[14] A model of a structural form describes all detailed flows in the economy. This contrasts with reductive models in which the entire or parts of the model are solved after which the model is used in the model analysis. The danger of using reductive models is the risk of overlooking changes in underlying variables.

[15] LINE also includes a price model. The prices in this version are stated exogenously.

a precise geographic reference to the variable explained (y)[16] and that spill-over and feedback mechanisms are included in the interregional economy.[17]

Methodically speaking, the analysis is unique because it is based on a local economy model with an unprecedented degree of detail; similarly, the ex post decomposition model with general interregional equilibrium models is also unparalleled. The methodology of the decomposition analysis is rooted in previous analyses of the correlation between regional development and transportation infrastructure. Madsen (2000) gives a theoretical account of how to estimate the effects of the Øresund Link on traffic and regional activity. A general interregional model ("M") is set up in which it is theoretically argued that the model results – for a selected variable – are a function of specific exogenous and endogenous variables. It is argued that the model should be an interregional General Equilibrium Model. Model results are then achieved by inserting values for the exogenous variables with and without a "political project", such as transportation costs before and after the opening of the fixed Øresund Link. The fluctuation in regional GDP – with and without a "political project" – can then be perceived as an indicator of the project's effect. Or the traffic before and after the opening of the fixed link can be perceived as the traffic-related effect.

The method is theoretically applied in transportation analyses (Madsen & Jensen-Butler, 2001), as various types of effect calculations are classified according to timeframe (ex ante and ex post calculations) and the technical requirements for the decomposition technique, i.e. sum restrictions for the effect of the individual decomposition contributions.

The technique is applied in Madsen et al. (1998), the Expert Committee (1998) and Jensen-Butler et al. (2002) using a simplified version of LINE to decompose the growth of per capita primary income and disposable income, respectively. The analyses used here were performed ex post.[18]

The decomposition technique is applied by Madsen & Jensen-Butler (2002) and Jensen-Butler & Madsen (2005) using a full version of LINE (interregional quantity model) to decompose the trends of per capita primary income and per capita disposable income for Danish municipalities.

In terms of methodology, the decomposition analysis differs from the methods used in the Danish debate. In this case models on reduced form were used, i.e. models involving one or two equations, e.g.:

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[16] The analysis reviews the significance of decomposing an income variable attributed to place of production or residence and concludes that it is very important if the variable is a place of production or place of residence variable. This has turned out to be one of the key points of criticism of the regional competitiveness model (Christoffersen & Windelin 2007).

[17] The analysis is interregional, meaning that the economic activity in a region depends not only on the economic activity in the region itself, but also on the activity of other regions. This has turned out to be one of the key points of criticism of the regional competitiveness model (Christoffersen & Windelin 2007).

[18] It should be noted that most analyses using LINE are ex ante analyses, where the effects of a given project are assessed within a specific future timeframe.

$$y_{t_1} - y_{t_0} = M^{R}_{q,ir}(Exovar_{1,t_1}, Exovar_{2,t_1}, Exovar_{3,t_1}, ..., Exovar_{n,t_1}, dExovar_{1,t_1-t_0}, dExovar_{2,t_1-t_0}, dExovar_{3,t_1-t_0}, ..., dExovar_{m,t_1-t_0}) \qquad (2)$$

where:

y: *earned income in total or per capita*

$M^{R}_{q,ir}$: *LINE, which is an interregional (ir) quantity model (q) on reduced form (R)*

Exovar: *variabel, which is exogenous in the regional development analysis*

dExovar: *the change in a variable, which is exogenous in the regional development analysis*

t_1, t_0: *final and start year for the growth analysis*

This shows a single-equation explanation of regional development. It shows that the equation can either examine concentration/deconcentration (income dispersion) or convergence/divergence (difference in average income). This example assumes that the model's exogenous variables – whether they are equal or differ – are derived (i.e. mathematically solved) from a theoretical structural model. Examples of this type of one-equation analyses are found in Dilling-Hansen & Smith (1997) and Heinesen & Groes (1997). In the case where regional economy is described using two equations, i.e. mathematically reduced from a structural model for two equations, the expression is altered. An example of a two-equation explanation of Denmark's regional economic development is found in Kristensen & Henry (1997).

When using reductive models, the econometric estimation of the equation(s) is used. When this involves a structural model, the model's equation will typically be calibrated, which is the case for LINE, for instance.[19]

In an international context, the ex post decomposition is distinctive by its use of an expanded interregional general quantity model. In addition, it is argued that the order of calculation in the decomposition should reflect the causal structure in the model used – and not merely be permuted to find the variations in the calculation result for different possible calculation sequences.

[19] Econometrically estimated solutions can be used for a few equations, e.g. taken from studies of national economic development.

B. The General Interregional Model and LINE

The study's most important research contribution concerns the set-up and solution of the general interregional model and the use of this model for analysing regional and local development and for analysing changes in the basis of the regional and local economy.

The task of formulating a general interregional local-economy model has been going on for about a decade and is continuously being documented in working papers and journals. The general interregional model comprises a quantity model describing the interregional economic activity measured in quantities (theoretically presented in ***Section 4***) and a price model describing the formation of prices and incomes (theoretically presented in ***Section 5***). The quantity and price model is merged in ***Section 6*** and formulated as a difference equation to theoretically illustrate the regional and local effects of demographic changes to the population. The local-economic model LINE (an empirical model comprising an interregional quantity and price model) is presented in ***Section 7*** (Madsen & Jensen-Butler 2002a and 2003), including ten different applications of LINE. ***Section 8*** presents a holistic empirical model where LINE is incorporated into an aggregate modelling system comprising a model for international economy (GTAP), national economy (AAGE), the local agricultural sector (ESMERALDA), transportation activities (MERGE) and LINE.

4. The General Interregional Quantity Model[20]

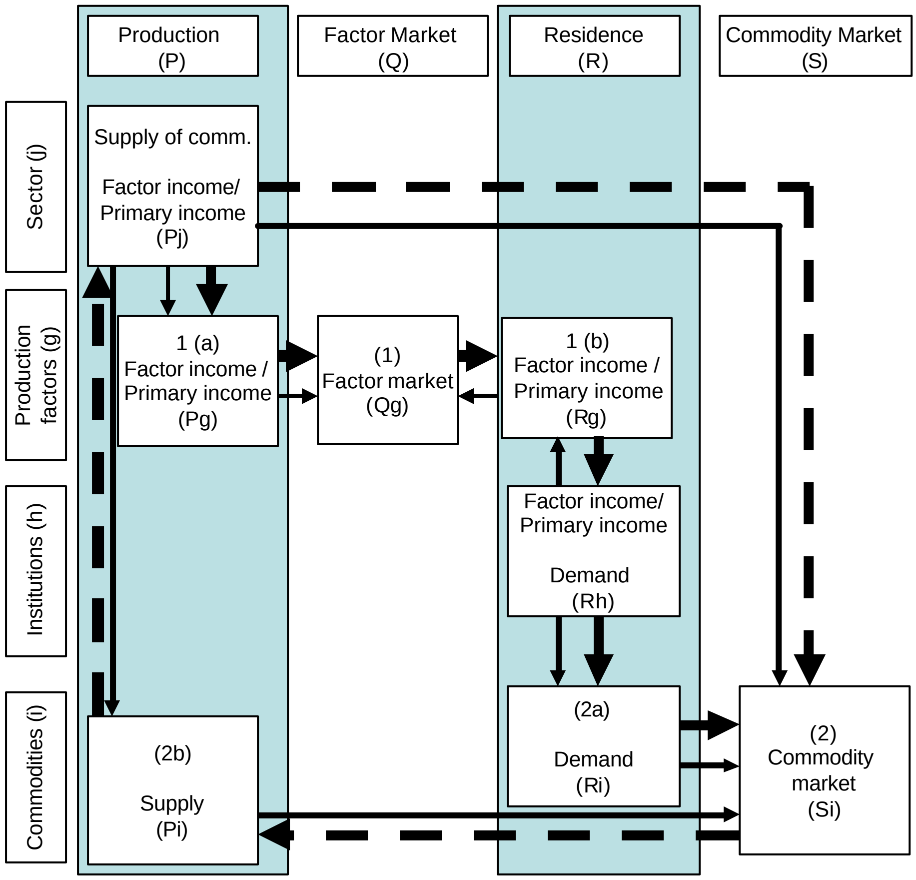
The underlying principles of LINE are generalised in Madsen (2007a and 2007b) in the formulation of theoretical, general interregional quantity model and price model, respectively. This section provides an overarching view of the general interregional quantity model presented in ***Section 4*** and the research leading to the formulation of this model. As shown, regional and not least local development are determined by a complex system of factors, some of which are determined by the area's geographic function and some by its socioeconomic function. In other words, the development within a geographic area is also determined by the economic development in other geographic areas, just as the development in one business sector depends on the development of other sectors, population trends, labour market, demand, etc. The general model for local economy presented in this study presents for the first time – by systematically applying the "two-by-two-by-two" principle – the internal and external economic interaction within the local economy, thereby reflecting various functions in the local economy and the interaction within the economy of the region concerned and with other regions and abroad.

4.1. Basic structure of the general interregional quantity model

The core of the study is made up of the local economy. By contrast with regional economy, the local economy encompasses more details (see Figure 1).

[20] Madsen, Bjarne (2007): The General Interregional Quantity Model.

Figure 1. Conceptual basis of the general interregional quantity model



Whereas the regional economy in a geographic context is delimited as a commuter and/or trade catchment area, the local economy also includes interaction within the factor market and the commodity market.

The *factor market* (field Qg in Figure 1) includes commuting between the place of production (Pg) and the place of residence (Rg). Commuting includes all factors of production: labour, capital and land, as well as subcategories of these factors of production. The production units geographically located at the place of production (Pj) generate demand for factors of production, i.e. demand for labour (jobs), capital and land (Pg). Institutions geographically belonging to the place of residence (Rh) provide factors of production (Rg): the households provide labour. The households/individuals, companies and businesses provide financial capital which finances the real capital at the place of production. The land is placed at the disposal of the land tenants[21] by the landowners where the landowners may be households/people, companies or businesses. In this context, the public sector is perceived as institutions that can own land and capital.

The supply and demand of the factors of production geographically meet at the place of factor market (Qg) where labour, capital and land are exchanged. The geographic exchange of the factors of production is commuting. Analyses of regional economy assume that the place of

[21] A land tenant can also be the landowner.

production and place of residence are the same, thereby eliminating commuting within the region. In so doing, regional models can be characterised as reductive models, whereas local models are structural models that explicitly model the geographic details.

In regional analyses, the model is also reductive as regards the description of economic activity: regional analyses usually consider economic activity alone, classified by business sector (j), while analyses of local economy also include a classification of economic activities according to institutions (h), factors of production (g) and commodities (i). Institutions are classified by type, such as households according to marital status and children/childless (Rh). Similarly, local analyses also consider the type of production factor (Pg and Rg) and markets for the factors of production (Qg): labour can be classified, for instance, by gender, age and education, while the market for land can be classified by use, e.g. housing, commercial or production purposes, etc. Financial capital can also be classified according to different types. This social accounting classification of factors of production can in turn be perceived as a structural description of the local economy, contrary to the regional analysis which implies a reduction of key characteristics, such as the type of factor markets and type of institution. Regional analyses can be interpreted as analyses that only consider one type of factor of production or one type of institution.

In the *commodity market*, the regional analysis model also involves reductions (see Figure 1): the local economy considers the supply of and demand for commodities as a two-step process, which has been reduced in the regional analysis to one. In the local economy, production is carried out at the place of production (Pj), while the demand is largely generated at the place of residence (Rh).[22] Supply and demand meet at the commodity market (Si). For this reason, the geographic interaction is divided into two steps in the local economic analysis: trade with commodities and services, which is the interaction between the place of production (Pi) and the commodity market (Si) and the purchase of commodities, which is the interaction between the place of residence (Rh) and the commodity market (Si). In the regional analysis this is reduced to a direct relationship between the place of production (Pj) and the place of residence without isolating the shopping segment from the trade segment.

Regional analyses of the commodity market are also reductive when considering the description of economic activity. The regional analysis solely considers economic activity classified by business sector, while the local economic analysis is divided into two steps: from sector to commodities (trade from Pj to Pi) and from commodities to institutions (shopping in private consumption: from Si to Rh) as well as from commodities to sector (shopping in intermediate consumption commodities). This "social accounting" classification of the local market represents a structural description of the activities, while the regional analysis is reductive.

The central concepts of place of production (P), place of residence (R), factor market (Q) and commodity market (S) were first developed in Madsen et al. (1999).[23] In the description of the interregional Social Accounting Matrix, priority was given to isolating a specific commodity market that was then used as the basis for dividing it into two parts: a demand aspect, involving shopping trips from place of residence (Ri)/place of production (Pi) to the

[22] The demand for raw materials originates at the place of production, however.

[23] Madsen et al. (1999) use the concept "place of demand" instead of "commodity market". "Commodity market" was subsequently introduced to emphasise that the concept involves aspects of both supply and demand.

commodity market (Si); and a supply aspect, involving trade trips from the place of production (Pi) to the commodity market (Si).

Madsen & Jensen-Butler (1999b) argue that the institutional input-output table (or sector-by-sector model, or the j-by-j model) should be divided into use matrices which break down the demand (for various types of demand) of business sector/components for commodities[24] (Pj for Si and Rh for Si, respectively) and into a make matrix (Pj to Pi), representing the transformation from the producing sectors to the commodities produced.

Thus, a local economic model makes it possible to achieve an adequate measurement of the multiplier effort of changes in the local economy. In the local economy, an economic impact disappears from the local economy when the commuting comes from outside of and into the local area, when shopping is done in other local areas or when the local area's inhabitants are tourists in other local areas. The effects also disappear from the local economy to the extent that the demand is met by production generated in other local areas. In this sense, the local economic model is more appropriate for describing leakages in the local economy whereas the conventional regional model considers nothing but trade leakages.

4.2. The two-by-two-by-two principle

The deliberations constituting a primary contribution to the doctoral dissertation and representing a new basis for formulating interregional economic models are generalised in the "two-by-two-by-two principle". The principle is illustrated in Figure 1.

First of all, the local economy – like the classic economy – includes two agents, i.e. producers (Pj) and institutions (Rh). Institutions can be groups of people linked by various relationships, e.g. households, municipalities/states, firms, companies, societies, etc. Types of institutions or households are classified in social accounting terminology (h). Producers are in turn groups of people who make up a common production activity. Production activities are divided into business sectors (j). The geographic concept of place of residence (R) is associated with the institutions. The geographic concept of place of production (P) is associated with the production.

Secondly, the local economy – like the classic economy – includes two markets: the commodity market (Si) and the factor market (Qg). The commodity market includes products and services. According to the social accounting tradition the commodity market is divided into commodity groups (i). The factor market includes factors of production (g) such as labour, capital and land. Similarly, factors of production are classified into various types, e.g. labour by gender, age and education.

The geographic concept of place of commodity market (S) is associated with the commodity market, while the concept place of factor market (Q) is associated with the factor market. The place of commodity market is the geographic location of the retail trade in so far as consumer

[24] The use matrix for raw-material demand involves a transformation from the consumption of raw materials classified by business sector to the consumption of raw materials classified by commodities. The use matrix for private consumption involves the breakdown of private consumption into consumption components for the private consumption of commodities.

goods are concerned, while the wholesale trade is the geographic location of the business sectors' investments and consumption of raw materials.[25]

For the factor market, the place of factor market is the geographic location where the factors of production are exchanged. As regards the labour factor of production, the conceptualisation is illustrated as legal agreements regarding the purchase and sale of labour that are concluded in the place of factor market. Like the commodity trade, there is also a retail and wholesale function for the purchase and sale of labour. The retail trade function involves the exchange of labour for final use (in households etc.), i.e. the activity is not resold in connection with the use of labour. For the wholesale trade function in the factor market, commodities are produced in connection with the use of the labour.

Thirdly, supply and demand are geographically linked in these two markets. The factor market involves commuting (from Pg to Qg and onward to Rg). The commuting goes from the institution's place of residence to the place of production via the factor market. If an actual geographic place of factor market exists, the commuting is divided into two transportation segments: from the institution's place of residence to the place of factor market and from the place of factor market to the place of production. In the case of capital, the place of factor market can be regarded as the place where financial capital is made available, e.g. loans (banking) or the place where companies place financing at the disposal of physical production units which can subsequently purchase physical capital over the commodity market.

The commodity market involves a more well-known division of the geographic transformation from place of production to the place of commodity market (from Pi to Si) and from the place of commodity market to the institution's place of residence (from Si to Ri) and to the production unit's place of production (from Si to Rj) respectively. The geographic transformation from place of production to the place of commodity market is denoted as normal trade, which can, if necessary, be subdivided into intraregional, interregional and international trade. The geographic transformation from the place of commodity market to the institution's place of residence or the production's place of production, respectively, is usually denoted as shopping or shopping trips. There are various types of shopping: local private consumption usually covers what is normally associated with shopping. However, tourism is a special type of shopping where the tourist moves from the institution's place of residence (private tourism)/the production unit's place of production (commercial tourism) to the place of tourism where the tourist region is the place of commodity market for the tourist (Madsen et al. 2003; Zhang et al. 2007). Governmental expenditure involves shopping where a place of residence exists for the governmental expenditure (typically the citizen who "receives" the governmental expenditure) and the place of commodity market where the governmental expenditure is carried out (typically the place of production for the commodity produced in the public sector) (see Madsen (2003) for a more detailed discussion of this issue). Investments and the consumption of raw materials by the business sectors also entail shopping. Shopping is often performed by making purchases in the wholesale trade.

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[25] It is worth noting in this context that a by-product exists for both the retail and wholesale trades where the retail trade also sells goods to the business sectors and to investment projects, i.e. performs the function of a wholesale trade, and the wholesale trade also to a certain extent performs the retail trade function for institutions.

4.3. Implementation of the two-by-two-by-two principle in the interregional quantity model for the local economy

The theoretical conceptual model can be applied in formulating an interregional macroeconomic model for the local economy. The general interregional quantity model is formulated in Section 4, graphically and mathematically.

The model is graphically depicted in Figure 1. As Figure 1 shows (the bold dotted lines) the graphic model is sequential as it moves clockwise and calculates from production to income (from Pj to Rh in Figure 1), from income to consumption (from Rh to Si and from Pj to Si) and from consumption to production (from Si to Pj). The structural form of the mathematic model is as follows:

$$y = M^{S}_{q,i,r}(g^{P}_{j}, Q^{P}_{j,g}, J^{P,Q}_{g}, J^{Q,R}_{g}, pv^{R,D}_{g}, H^{R}_{g,h}, pu^{R}_{CP,h}, b^{R}_{CP,i}, B^{R}_{CP}, S^{R,S}_{CP,i}, b^{P}_{IC,i}, B^{P}_{IC}, S^{P,S}_{IC,i}, d^{S,F}_{i}, T^{S,P}_{i}, D^{P}_{i,j}, z^{P,F}_{i}, u^{S,F}_{IC,i}, u^{S,F}_{CP,i}, u^{S}_{CO,i}, i^{S}_{I,i}) \quad (3)$$

where:

g^{P}_{j} : *labour content of production*

$Q^{P}_{j,g}$: *qualification, age and gender structure of employment*

$J^{P,Q}_{g}$, $J^{Q,R}_{g}$: *commuting coefficient for place of production and place of recidence*

$pv^{R,D}_{g}$: *labour cost index*

$H^{R}_{g,h}$: *type of household by type of labour*

$pu^{R}_{CP,h}$: *private consumption privat index*

$b^{R}_{CP,i}$: *private consumption shares*

B^{R}_{CP} : *commodity consumption of intermediate consumption*

$S^{R,S}_{CP,i}$: *shopping pattern for intermediate consumption*

$b^{P}_{IC,i}$: *intermediate consumption share*

B^{P}_{IC} : *the commodity composition of intermediate consumption*

$S^{P,S}_{IC,i}$: *shopping pattern for intermediate consumption*

$d^{S,F}_{i}$: *import share of imports from abroad*

$T^{S,P}_{i}$: *intra – and interregional trade structure*

$D^{P}_{i,j}$: *commodity composition of production*

j : *sectors*

g : *production factors*

h : *institutions / households*

i : *commodities*

P : *place of production*

Q : *place of factor market*

R : *place of residence*

S : *place of commodity market*

It is apparent that M is a structural model (S) which is interregional (ir). The production (y) depends on the exogenous demand (variables in the second line of the equation) and on a number of transformation matrices (variables in the first line of the equation).

Solving the structural model results in the following expression in reduced form.

$$
\begin{aligned}
y &= M^{R}_{q,ir} \\
&= Multiplier(g^{P}_{j}, Q^{P}_{j,g}, J^{P,Q}_{g}, J^{Q,R}_{g}, pv^{R,D}_{g}, H^{R}_{g,h}, pu^{R}_{CP,h}, b^{R}_{CP,i}, B^{R}_{CP}, S^{R,S}_{CP,i}, b^{P}_{IC,i}, B^{P}_{IC}, S^{P,S}_{IC,i}, d^{S,F}_{i}, T^{S,P}_{i}, D^{P}_{i,j}) \\
&\quad \bullet Exogenous\ variables(z^{P,F}_{i}, u^{S,F}_{IC,i}, u^{S,F}_{CP,i}, u^{S}_{CQ,i}, i^{S}_{I,i}) \ldots\ldots\ldots (4)
\end{aligned}
$$

It is apparent here that the model's solution consists of a multiplier and a number of exogenous variables.

The quantity model is denoted as a Keynesian demand model with: a) interregional supply from place of production to place of residence, from place of residence to place of commodity market and from place of commodity market to place of production; and with b) supply among various SAM groups, equivalent to the two-by-two-by-two principle.

The general interregional quantity model differs in several ways from the existing tradition for interregional input-output models, formulated by, *inter alia*, Isard (1951) and Chenery-Moses (Chenery 1953, Moses 1955): first of all, the sector-by-sector relationship, the sector and commodity relationship (use matrices) and between commodities and sectors (make matrices) (Madsen & Jensen-Butler 1999b). It is argued that model in structural form more adequately describes the producers' behaviour as both the composition of raw materials (use matrix) and the composition of commodities (make matrix) are explicitly modelled. The demand for raw materials is geographically classified in the transition from place of production to place of commodity market (use matrix) which establishes shopping with raw materials and from the place of commodity market to the place of production (make matrix) which describes the trading of finished commodities. In this respect, the general interregional model differs from the respective Isard and Chenery-Moses models. The Isard model links final use in one region to production in another region, while the Chenery-Moses model uses a pool approach.

Secondly, the relationship between production and income is formulated in a quantity relation between a) production and employment and b) employment and income. The relation is subdivided into a relation between:

- production and jobs, which determines the number of jobs;
- jobs and employment, which determines commuting and employment according to place of residence; and
- employment, level of income, which determines the value of the income.

In so doing, a distinction is made between place of production (P), place of factor market (Q) and place of residence (R) and between activities classified according to business sector (j), factor groups (g) and according to types of household (h).

Interregional input-output models that also include induced effects – e.g. Miyazawa (1976) – establish a direct link between production value and income which is regarded as a reduction of the underlying relationship between production, employment and income. Consumption is exogenously determined in the classic Isard and Chenery-Moses models, and there is no classification of income by factor group or type of household, whereas Miyazawa classifies types of households.

Thirdly, the relationship between demand and production is divided into a relationship between demand by residence and demand by place of commodity market and into a relationship between place of commodity market and place of production. These two relationships are reduced to one in the Isard and Chenery-Moses models. The division involves both a transformation from households to commodities and a transformation from commodities to production sector. Geographically speaking, this splits the flow of commodities into flows of commodities from place of residence to place of commodity market (shopping/tourism) and from place of commodity market to place of production (trade).

The quantity model is mathematically revalued in ***Section 4*** by applying the two-by-two-by-two principle. The mathematical formulation of the general interregional quantity model is based on Greenstreet (1987) which includes make, trade and use matrices in the formulation of the interregional quantity model. The general interregional quantity model is analytically solved and thus represents a qualification of the "Leontief inverse" so that it also includes geographic transformations such as trade, commuting, shopping and tourism and SAM transformations from production sectors to factor groups, from factor groups to institutions, from institutions to commodities and from commodities back to production sectors.

4.4. The two-by-two-by-two principle and a typology for regional and local economies

Regions are usually classified on the basis of specialisation and productivity which usually reflect a link to trade theory where a local area specialises within the functions in which the area has comparative advantages. Localisation coefficients are normally used for describing specialisation. ***Section 4*** uses the general interregional quantity model as the basis for classifying local economies according to their local economic function. This classification links local areas according to both specialisation and interaction: firstly certain local areas are characterised by their function as a (net) exporter of commodities where a distinction is made between primary, secondary and tertiary production, for instance. Secondly, certain local areas are distinguished by their function as places of residence with significant (net) commuting. Here, too, areas of residence can be subdivided according to the prevalence of specific population segments (e.g. municipalities with large numbers of elderly or working people). Thirdly, some municipalities are distinguished by their function as a place of commodity market, e.g. retail-trade or wholesale-trade centres or for sale and production service, e.g. cultural activities or specialised public service (e.g. hospital production).

The key aspect of considerations concerning the classification or typology of local areas is therefore not only the local area by itself, but also on the local area's position in the local economy. When regarded as a dependent local economy, the derived effects, or the multiplier effect, are less the greater the leakages away from the area, regardless of whether this involves trade, shopping, tourism or commuting.

The typology was applied by Zhang et al. (2007) who use LINE to perform multiplier calculations showing the consequences of modified tourism in various regions of Denmark, i.e. Greater Copenhagen as a metropolitan area, major urban areas, rural areas linked with large urban areas and rural areas that are weakly linked with urban areas. The article explains the multiplier effects of increased tourism, of the scope of leakages within the individual area, i.e.

trade with other regions and abroad, inward and outward commuting in the area, shopping into and away from the area, and tourism entering and leaving the area.

5. The General Interregional Price Model[26]

The price model is the counterpart of the quantity model in an input-output modelling context. In an input-output price model, the price is determined on the basis of a simple add-on principle. Whereas the quantity model is regarded as a model that includes backward linkages, i.e. quantity effects on external suppliers (indirect effects) and derived consumption (induced effects), the price model encompasses the forward linkages. The price model calculates how a cost change, e.g. increased wage costs, is passed on to the enterprises' prices, which is in turn passed on to prices of commodities sold to the next link of the production chain, etc.

In this context it is relevant to model these domino-effect mechanisms in a local economy. How do cost changes affect the price of products produced within a given area? And how are costs and prices affected by transportation costs for commodities transported from one place of production to a commodity market and on to the next producer in the production chain, etc.? And how is the price of commodities delivered for final use, e.g. private consumption or exports abroad, affected by the cost of producing the commodity and transporting it to the end-user?

The task of formulating a general interregional price model arose as part of the modelling of regional consequences of infrastructure investments and regulation of the transportation sector (cf. ***Main Section D***). Changes to transportation costs affect the prices of commodities (products and services). In the initial tasks, the modelling of transportation effects solely involved the modelling of "external influences". In this respect, the transportation cost affects the export price (competitiveness) which in turn affects the volume exported, which in turn affects the demand for the commodity for the interregional quantity model (Jensen-Butler & Madsen, 1996, 2004). The modelling of costs and prices was subsequently and fully incorporated into the general interregional price model which, together with the general interregional quantity model, is included in the overall general interregional model (Madsen et al. 2002a, Madsen & Jensen-Butler 2004b; and Madsen 2007b).

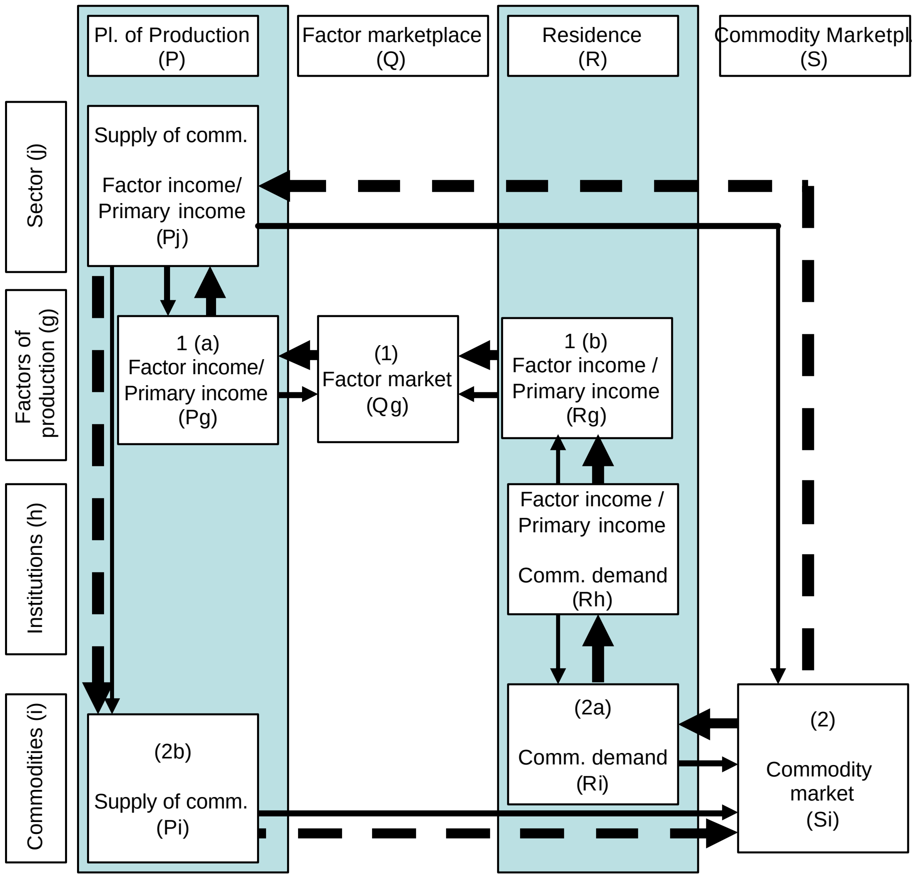
The general interregional price model presented in ***Section 5*** provides the first detailed description of the formation of costs and prices in the local economy, in contrast with the general national price model (Miller & Blair 1985), the interregional version of the input-output price model (Toyomane 1986) or the interregional General Equilibrium Models (Bröcker 1998). This basically involves the same concepts and model structure that were used in the general interregional quantity model, i.e. the two-by-two-by-two principle, as the quantity model's coefficients are included as weights in the calculation of cost and price. The interregional price model is quite useful because it describes the impact of cost and price changes in local areas, making it an important element in determining the regional and local multipliers.

5.1. Basic structure of the general interregional price model

An illustration of the formation of costs and prices in the local economy is shown in the following figure (see Figure 2):

[26] Madsen, Bjarne (2007): The General Interregional Price Model.

Figure 2. Conceptual basis of the general interregional price model



Graphically, the price model follows the quantity model (see Figures 1 and 2), the only difference being that it moves in the opposite direction, i.e. counter-clockwise (cf. the dotted arrows). Like the quantity model, the general interregional price model is sequential. The price model follows a simple mark-up principle which means that cost changes are passed on penny for penny to the prices in the next link of the production chain.

The general interregional price model differs in a number of ways from the existing tradition for interregional input-output models: as is the case for interregional quantity models, the traditional method is to use the institutional approach where the supply between production sectors is reductively described. The general interregional price model divides the interrelationship between production sectors, to interrelationships between production sectors and commodities (use matrices) and between commodities and production sectors (make matrices) (Madsen and Jensen-Butler 1999b). The general interregional price model transforms cost and price effects from business sectors to commodities and from commodities back to production sectors. Geographically, the price formation process is divided into the transition from place of production to place of commodity market, which describes the transition from place of production (Pi) to place of commodity market (Si) (interregional trade), and the transition from place of commodity market to the place of production (shopping with intermediate consumption commodities), which establishes shopping involving raw materials from the place of commodity market (Si) to the place of production (Pi). In this respect, the general interregional price model differs from the respective Isard and Chenery-Moses models (see

Toyomane 1986). Toyomane links the price to final use in a region to the price of production in another region.

Secondly, the generation of income is formulated on the basis of the interregional quantity model's relationship between production and employment and between employment and income. The formation of incomes is subdivided into relationships between:

- employment, level of income and income;
- jobs and employment (commuting); and
- production and jobs.

In so doing, a distinction is made between place of residence (R), place of factor market (Q) and place of production (P), and between activities classified according to types of household (h), factor groups (g) and business sectors (j). Interregional input-output models do not include induced price and income effects – see e.g. Toyomane (1986) which only deals with indirect effects.

5.2. Implementation of the two-by-two-by-two principle in the interregional price model for the local economy

The price model is mathematically revalued in ***Section 5*** (Madsen 2007b) by applying the two-by-two-by-two principle.

$$px = M^{S}_{p,ir}(D^{P}_{i,j}, T^{S,P}_{i}, d^{S,F}_{i}, S^{P,S}_{IC,i}, B^{P}_{IC}, b^{P}_{IC,i}, S^{R,S}_{CP,i}, B^{R}_{CP}, b^{R}_{CP,i}, H^{R}_{g,h}, J^{Q,R}_{g}, J^{P,Q}_{g}, Q^{P}_{j,g}, g^{P}_{j},$$
$$pz^{S,F}_{i}, pu^{P,F}_{IC,i}, pu^{R,F}_{CP,i}, pvx^{R}_{h}, pvx^{R}_{g}, pv^{P,F}_{g}, pvx^{P}_{j}) \quad \text{.........(5)}$$

where

px : *the price of local production*

$pz^{S,F}_{i}$: *the price of imports from abroad*

$pu^{P,F}_{IC,i}$: *the price on intermediate consumption of commodities bought directly from abroad*

$pu^{R,F}_{CP,i}$: *the price on private consumption from commodities bought directly abroad*

pvx^{R}_{h} : *the cost of the share of income which is not consumed*

pvx^{R}_{g} : *the cost index for the part of income earned abroad*

$pv^{P,F}_{g}$: *the cost on income earned in production by persons living abroad*

pvx^{P}_{j} : *a cost index for the share of income from production which is independent of prices on private consumption*

A cost index for the income earned in production, which is determined independent of the price on private consumption commodities. The price of a local production is determined in the price model (p) which is on structural form (S) and interregional (ir). The price of production is a function of a number of exogenous price and cost elements ranging from the price for the part of the income that is fixed independently of the price for the private consumption, to the price of imports from abroad. In addition, the price of production depends on a wide range of transformation coefficients. The transformation coefficients are taken from the quantity model. Solving the structural model results in the following reduced form expression.

$$px = M^{R}_{p,ir}$$
$$= Multiplier(D^{P}_{i,j}, T^{S,P}_{i}, d^{S,F}_{i}, S^{P,S}_{IC,i}, B^{P}_{IC}, b^{P}_{IC,i}, S^{R,S}_{CP,i}, B^{R}_{CP}, b^{R}_{CP,i}, H^{R}_{g,h}, J^{Q,R}_{g}, J^{P,Q}_{g}, Q^{P}_{j,g}, g^{P}_{j})$$
$$\bullet ExogenousVariables(pz^{S,F}_{i}, pu^{P,F}_{IC,i}, pu^{R,F}_{CP,i}, pvx^{R}_{h}, pvx^{R}_{g}, pv^{P,F}_{g}, pvx^{P}_{j}) \quad \text{.........(6)}$$

It is apparent here that the model's solution consists of a multiplier and a number of exogenous variables.

5.3. The two-by-two-by-two principle and typology for regional and local economies

The presentation of the general interregional quantity model included establishing a typology for classifying local areas. After reviewing the general interregional price model, it is apparent that this model supports the classification, meaning that the greater the leakages the lesser the multiplier – for both the price and the quantity model. As a result, the classification of local areas is also relevant in studying the cost and price effects.

This is illustrated on the basis of typical local or regional development projects. The effect of a typical project can be described in two ways: either it directly increases the demand for a region's products or the demand is indirectly increased by reduction in costs and prices, which in turn leads to increased exports and reduced imports and thus increased production, income and employment. In the first case, the reasoning is within the quantity model, while in the other, the reasoning starts in the price model and ends in the quantity model.

Looking first at the direct increase of demand for the products of a local area, the derived effects or the quantity multiplier will be smaller, the smaller the intraregional trade, shopping, tourism and commuting for the local area are. Looking next at the indirect increase of demand for the products of a local area, achieved through cost and price reductions, the derived effects or the quantity multiplier will also be smaller, the smaller the intraregional trade, shopping, tourism and commuting for a local area are. This is because the effects of competitiveness and cost and price will be smaller, the larger the intraregional trade, shopping, tourism and commuting are. This reduces the favourable effects on export and import and thus on production, income and employment.

5.4. Simultaneous solution of the general interregional quantity and price model

It is important to describe the local economy if the point of departure is that the price system influences the quantity system and the quantity system influences the price system. To make a more exhaustive description of the local economy, the two systems must be linked, after which the simultaneous model is solved. As is apparent in the above, mathematical solutions for the general interregional quantity and price models can be derived separately for each model. The simultaneous solution for the local economy can be found if it can be assumed that there is a very simple link between changes in export quantities and prices. An explanation is given for the fact that the possibilities of finding a simultaneous solution for the general interregional quantity and price model are smaller the greater the complexity of the links between the quantity and price model.

6. Modelling Demography and the Regional Economy: An Interregional General Equilibrium Modelling Framework[27]

A key problem arising precisely from the efforts to find a simultaneous solution for the general interregional quantity and price model is the modelling of changes to the local and regional economies. Changes often affect the economy's formation of both quantities and prices. In a modelling perspective, this puts demands on the linking of the general inter-

[27] Bjarne Madsen (2007): Modelling demography and the regional economy: an interregional General Equilibrium Modelling framework.

regional quantity and price model. In addition, the transformation matrices in the two sub-models cannot be assumed to be constant. To illustrate this, ***Section 6*** presents a model-based analysis of the local effects of demographic development which in the years ahead will be typified by an aging population. The general interregional quantity and price model is in this section formulated in changes, and the two sub-models are linked to illustrate the effects of demographic shifts.

6.1. The general interregional quantity and price model formulated in difference

As was shown in ***Sections 4 and 5***, the advantage of formulating the general interregional model using levels is that a mathematical solution can be derived for the model. The drawback is that it becomes paramount to assume linear functions in order to solve the model. The advantage of formulating the model in difference equations is that it is possible to use non-linear functions which when formulated in difference equation become linear and can subsequently be solved. Another advantage is that it is possible to perceive (some of) the solution for the difference-equation model as multipliers.

There is a tradition within interregional general equilibrium models to formulate model equations in difference so it is possible to take account of adjustments in production, consumption, trade structures, etc. An example of this is the Australian MMRF-GREEN model, cf. Peter et al. (2001) and Bröcker (1998). The contribution of this doctoral dissertation is to include modelling of the local economy into this tradition by formulating the general interregional quantity and price model based on the two-by-two-by-two principle in difference.

Specifically, in ***Section 6*** all equations in the quantity and price model are formulated as difference equations, which are solved as two sub-models in the same way that the model was solved using levels (cf. ***Sections 4 and 5***). Prior to this, selected parts of the model are changed to reflect the problem relating to the relation between the local economy and demographic development.

Firstly, it is assumed that the participation rate (for the workforce) is affected by the average income so that changes in the participation rate depend on changes in the average income of the respective age groups, i.e. a decline in the average income leads to a decline in the participation rate.

Secondly, productivity is assumed to depend on the age composition of employment within the respective sectors. It is assumed that the ageing of the employed in a sector reduces productivity.

Thirdly, it is assumed that the age composition of employment within the respective sectors will depend on the relative average incomes. If the average income of a given age group grows relative to the average income of other age groups, the percentage of employees in the given age group in the respective business sectors will decline.

Finally, it is assumed that income changes depend on the difference between the local area's unemployment rate and the natural unemployment rate in the local area.

6.2. Ageing and local economic development

Using the model as the point of departure, the long-run and short-run local economic effects of ageing are analysed. In the short run, ageing will lead to a decline in unemployment for both younger and older age groups. For both groups this will be relative to the natural unemployment rate which is assumed to be in balance in the basic situation. Other factors being equal, growing unemployment leads to relatively higher wage increases, thus growing export prices and, with that, declining exports. Declining exports means declining demand, production, income and employment. Unemployment that declined initially will subsequently grow again and adjust in the direction of the natural unemployment rate. In the long term, unemployment will return to the natural level, productivity will be at a lower level, higher prices, lower exports and higher imports and lower production income and employment.

Regionally, the effects differ and follow the typology established in connection with the presentation of the general interregional quantity model. The effects subsequently depend on the direct effects of ageing on local areas and the multipliers for various types of local areas, including the extent to which ageing is significant to the size of the multipliers.

7. Theoretical and Operational Issues in Sub-regional Modelling, Illustrating the Development and Application of the LINE Model[28]

LINE was developed in the late 1990s and the early part of the millennium's first decade. LINE is unique because – in an international context – it provides a description of local economic activity in the local economy with unprecedented detail. The development of LINE was largely controlled by the structure of the general interregional quantity and price model, i.e. the two-by-two-by-two principle. In addition, LINE reflects the data-related possibilities in Denmark's regional and local economic statistics, just as the development of LINE draws on the lessons learned from the use of AIDA,[29] an interregional model for Danish counties developed in the late 1980s and early 1990s. LINE is documented by Madsen et al. (2002a) and Madsen & Jensen-Butler (2005).

7.1. From AIDA to LINE

If the structure of AIDA is used as the point of departure for the description, the development from AIDA to LINE can be described as follows:

First of all, LINE represents a transition from the modelling of economic activity of counties to flexible geographic units, e.g. municipalities, commuting catchment areas, or municipalities subdivided into smaller units.

Second, there is a transition from the use of institutional input-output models to structural input-output models. In international traditions, regional economic models are largely based on an institutional approach where economic interaction between sectors is modelled as a direct interaction between sectors, expressed in the institutional or sector-by-sector input-output model. The emergence of regional and interregional SAMs has made it natural to work instead with two input-output matrices for linking the interaction between sectors. This partly includes the make matrix, showing which commodities are produced by a given sector, and use matrices, showing which (raw) materials are in demand by these sectors and which (consumer) goods are in demand by institutions (e.g. households). Madsen & Jensen-Butler (1999b) argue that splitting the input-output models into two subsidiary models is more

[28] Bjarne Madsen and Chris Jensen-Butler (2004): Theoretical and operational issues in sub-regional modelling illustrated the development and application of the LINE Economic Modelling, Volume 21, Issue 3, pp. 471–508.

[29] Documentation of AIDA is provided by Madsen (1992) and Jensen-Butler & Madsen (1996).

satisfying theoretically speaking and closer to the data collected by statistics agencies for use in setting up (national) input-output tables.
Third, three geographic concepts are used: place of production, place of residence and place of commodity market[30] – as opposed to AIDA which only includes one, i.e. place of production.

Fourth, LINE also includes a SAM axis with sectors, types of labour, types of households and groups of commodities. Compared to AIDA, this significantly expands the description of economic activity, in that AIDA solely included a division into sectors.

Fifth, interregional (and international) trade is modelled in commodities, whereas AIDA modelled trade in sectors. This development is a theoretical improvement, on the one hand, as commodity trade – as the phrase implies – occurs in commodities. At the same time, the transition to commodities simplifies the model, as the supply between sector and end-user is divided into three simple steps: from sector to commodity (use matrix), from place of commodity market to place of production (trade) and from commodities to business sectors (make matrix). In the institutional approach used in AIDA, interaction is established between each supplying sector and each recipient sector/end-user which in the case of regions greater than ten results in an extremely large number of trade flows and required data deriving from this.

Sixth, trade margins[31] and commodity taxes[32] are explicitly modelled in LINE and linked to commodities and use. From this, use is calculated in terms of purchase prices and basic prices respectively. The modelling is geographically linked to the place of commodity market. Compared to AIDA, this modelling process is theoretically simpler and more satisfying, and the data required are less, even if the modelling is substantially expanded.

Seventh, wage incomes, transfer payments and taxes are modelled with a much greater degree of detail and broken down by types of labour and families.

Eighth, private consumption is modelled, divided into local private consumption and tourism income. Local private consumption is broken down by place of residence, place of commodity market and types of commodities, while tourism income from Danes on holiday in Denmark and foreign tourism is broken down by tourist category (hotel guests, campers, etc.) and place of residence/nationality. Domestic tourism was not modelled endogenously in AIDA.

7.2. From the general interregional model to data possibilities

The development of LINE inevitably had to consider data possibilities. In this respect, LINE did not fully conform to the structure of the general interregional model. The following adjustments should be emphasised which reflect data limitations, some of which reflect expansion and other simplification of the general two-by-two-by-two principle.

First of all, the concept of place of factor market is not included, because this concept is not included in the statistics. In practice, place of residence for a factor of production can be interpreted as a place of factor market. From a data-processing viewpoint, only the factor of

[30] In some of the first presentations of LINE, the place of commodity market is designated the place of demand.
[31] Trade margins are divided into retail-trade and wholesale-trade margins.
[32] Commodity taxes are divided into VAT and other commodity taxes.

production's place of residence and place of production can be registered and, as a result, the place of factor market is not included in LINE.

Second, only part of the gross value increment accrues to people (i.e. the primary income), which continues on through commuting, personal taxation, etc. In the long term, it will be possible for company income, etc., to receive the same treatment as primary income, if it is possible to obtain information from the income system. It will also be possible to establish a relationship between (gross) investments and savings.

Third, there is a need to illustrate the interaction among institutions, such as households, the public sector and companies. The interaction between the household sector and the public sector (e.g. taxes, transfer payments) is included in LINE, to be able to assess the economic strength of the households, for instance, by determining the disposable income. For this reason, the interaction involving factor of production, households and the public sector is included in LINE.

Fourth, a two-step procedure for modelling private consumption is included in LINE: first, households – geographically attributed to place of residence – make decisions regarding private consumption for commodity groups. Secondly, private consumption is more specifically broken down by commodity at the place of commodity market where the decision to break down the consumption of commodities is performed. This nesting of private-consumption decisions is included in LINE because the national data used as the overarching framework for the estimation of trade balances has a nested structure. The same nesting is included for other types of use, such as governmental expenditure, where decisions regarding public service at an overall level are made at the place of residence, where an allotment of public service occurs, whereas decisions regarding the breakdown of detailed commodities takes place at the place of commodity market and place of production, respectively (governmental raw materials and governmental consumption of raw materials broken down by commodities).

Fifth, private consumption is divided in LINE into local private consumption and tourism. This subdivision is used in various analyses of tourism's regional economic significance, where the fact that LINE differentiates between Danes' tourism in Denmark and abroad is exploited, while tourism in Denmark is subdivided into one-day tourism and accommodation-based tourism.

Sixth, various value concepts are included in LINE. Purchase prices or market prices are used for commodities in the value determination, i.e. prices including commodity taxes and trade margins. The supply of commodities is calculated in basic prices at the place of production and up to the place of commodity market where commodity taxes and trade margins are added to the price. Interregional trade is subsequently calculated in basic prices. Basic prices are defined as the value of the production ex works, exclusive of commodity taxes, net paid by the manufacturer.

Finally, various price levels are included in LINE; i.e. fixed and current prices. LINE consists of an interregional quantity model and a price model. The quantity model is used for calculating production and demand in fixed prices, while the price model contains a price index for production and demand. Based on the quantity model's information about production and demand in fixed prices and the price model's price index, production and demand can be implicitly calculated at current prices for the year.

7.3. LINE applications

The results of ten different applications of LINE are summarised in Madsen & Jensen-Butler. The key aspect of the presentation is that LINE can be configured in accordance with the specified needs of the analysis (see table 3):

First, the table shows the geographic unit used in each analysis (municipalities, counties or commuter catchment areas).

The next specification is whether the version of LINE used analyses in terms of place of production, place of residence and/or place of commodity market, respectively. Some of the first analyses based on LINE are limited to place of production and place of residence, while virtually all subsequent analyses are fully expanded analyses geographically. This is followed by a specification of the extent to which a classification of economic activities according to a social accounting matrix specification is used. First of all, sectors are included in most analyses. The more extensive and subsequent analyses also include a subdivision of economic activity according to factors of production, type of household and commodity groups. Employment and personal incomes are especially subdivided in terms of age, gender and education.

Furthermore, the specification indicates the parts of LINE which are included, i.e. whether the quantity and/or price model is included, which in some instances only includes “quantity model I” (modelling primary income and employment according to place of work and place of residence respectively, and on the basis of this, calculating taxes and transfer payments), while “quantity models I and II” are included in expanded versions of LINE. Finally, it is specified whether the quantity and price models are linked through relationships between demand (from the quantity model) and prices (from the price model).

The final categories indicate whether the model analyses are “top-down” (using overarching national or international analyses as the point of departure for subdividing for regional or local levels) or “bottom-up” (based on detailed model calculations for small units which are subsequently aggregated for overall national results).

Table 3. Examples of studies which include the use of LINE

Studies	Regions:				SAM components							Model circles				Model hierarchy	
	Regional level	Place of production	Place of residence:	Commodity market-place	Bussiness sector	Factors			Institutions	Needs	Com modit ies	Quantity model I	Quantity model II	Price model	Links between 2 sub-models	Top-down	Bottom-up
						Age	Gender	Education									
Rural development/scenarios																	
Rural development[1)]	Munici-palities	X	X		X				X			X					X
Agricultural and environmental regulation[2)]	Munici-palities	X	X	X	X				X	X	X	X	X			X	
Industrial development[3)]	Munici-palities	X	X	X	X				X	X	X	X	X				X
Tourism[4)]	Counties	X	X	X	X	X	X	X	X	X	X	X	X				X
Settlement[5)]	Municipalities	X	X	X	X	X	X	X	X	X	X	X	X				X
Welfare scenario[6)]	Munici-palities	X	X		X				X			X				X	
Other analyses:																	
Greater Copenhagen's development[7)]	Munici-palities	X	X		X				X			X					X
Road pricing[8)]	Counties	X	X	X	X				X	X	X	X	X	X			X
Great Belt rates[9)]	Counties	X	X	X	X				X	X	X	X	X	X	X		X
Income-growth decomposition[10)]	Commuter catchment areas	X	X	X	X	X	X	X	X	X	X	X	X				X
Labour market[11)]	Counties	X	X	X	X	X	X	X	X	X	X	X	X			X	
New economy, Greater Copen-hagen[12)]	Counties	X	X	X	X	X				X	X	X	X				X

1) Jensen-Butler et al. (2002)
2) Hasler et al. (2002)
3) Andersen & Christoffersen (2002)
4) Zhang (2001)
5) Andersen (2002)
6) Dam et al. (1997)
7) Expert Committee (1998)
8) Madsen & Jensen-Butler (2001)
9) Madsen et al. (2002)
10) Madsen and Jensen-Butler (2005)
11) Lundtorp et al. (2005)
12) Telle & Tanghøj (2002)

8. A Systems Approach to Modelling Regional Economic Effects of Road Pricing[33]

When models are used in analyses of regional or local economies, the analysis is often limited by the regional or local economic model. In addition, more detailed models are often required, e.g. for agricultural production, to illustrate the consequences satisfactorily. In an overarching perspective, a systems approach is required that vertically[34] includes the effects of the international level at a lower geographic level, effects from the national level to the regional and local level and finally from the regional to the local level. Horizontally, there is a need to study the effects between economic consequences for the local economy as regards specific businesses or commodities respectively. This could involve how changes in interregional commodity trade, commuting, shopping and tourism affect the transportation commodity, or the effects between the agricultural business and other aspects of regional and local economy.

8.1. Modelling system

The need to apply a broader, more comprehensive modelling system emerges in several different analyses: within the transportation area, the interaction between the transportation sector and the (inter)regional economy is reviewed. In an analysis of the regional consequences of a Great Belt Link, Madsen & Jensen-Butler (1991) describe the demand for transportation as a derived demand where the need for transportation is largely determined by regional and local economic development.

Madsen & Jensen-Butler (1999a) apply different quantitative models to illustrate the regional consequences of a fixed link across the Fehmarn Belt. The choice of an "eclectic approach", which includes different models not based on the same theoretical point of departure and which may be reciprocally inconsistent is naturally second best. But as there is great interest in illustrating the consequences of establishing a fixed link across the Fehmarn Belt, and as no combined consistent modelling system was available for illustrating the interaction between regional and local economy on the one hand and the transportation system on the other, an eclectic approach was selected.

Consequently, different modelling instruments were used:

a) a traffic model for traffic between Scandinavia and the European mainland;
b) a regional model for economic activity in Storstrøm County (EMIL);
c) an interregional model for Danish counties (AIDA); and
d) a potential model for illustrating changes in competitiveness for various regions in Europe.

This set of models was used for calculating the regional and local consequences of production, income and employment of the following:

1) replacing ferry traffic with a fixed link (EMIL);
2) rerouting corridor traffic from Sweden's Baltic routes and the Jutland corridor to the Fehmarn Belt corridor (traffic model and EMIL);

[33] Bjarne Madsen, Chris Jensen-Butler, Steen Leleur & Jacob Kronbak (2007): *A Systems Approach to Modelling the Regional Economic Effects of Road Pricing*. In "Traffic, Road Pricing and the Environment" from the series "Advances in Spatial Science", published by Springer.

[34] The argumentation is based on the assumption that the system is top-down, as opposed to bottom-up (i.e. where the local and regional levels determine the higher levels). An alternative approach is to study the micro and macro levels where the macro level in the top-down approach determines the micro level, while the micro level in the bottom-up approach determines the macro level. In both instances, integrated approaches are also conceivable, i.e. involving the interplay between the two levels.

3) a higher level of activity in the accommodation and restaurant trades (traffic model and EMIL, respectively); and
4) an improved and impaired accessibility for various regions of Scandinavia and the Continent (the potential model and AIDA).

For want of an overall consistent analysis instrument, the results of the subsidiary analyses were combined to illustrate the overall effect.

Deliberations regarding the structuring of an overall integrated modelling system for evaluating and projecting regional development and the transportation infrastructure were expanded in Madsen (2000), and Madsen & Jensen-Butler (2001), in which the requirements for data and models were described in an ex post evaluation of the fixed link across Øresund.

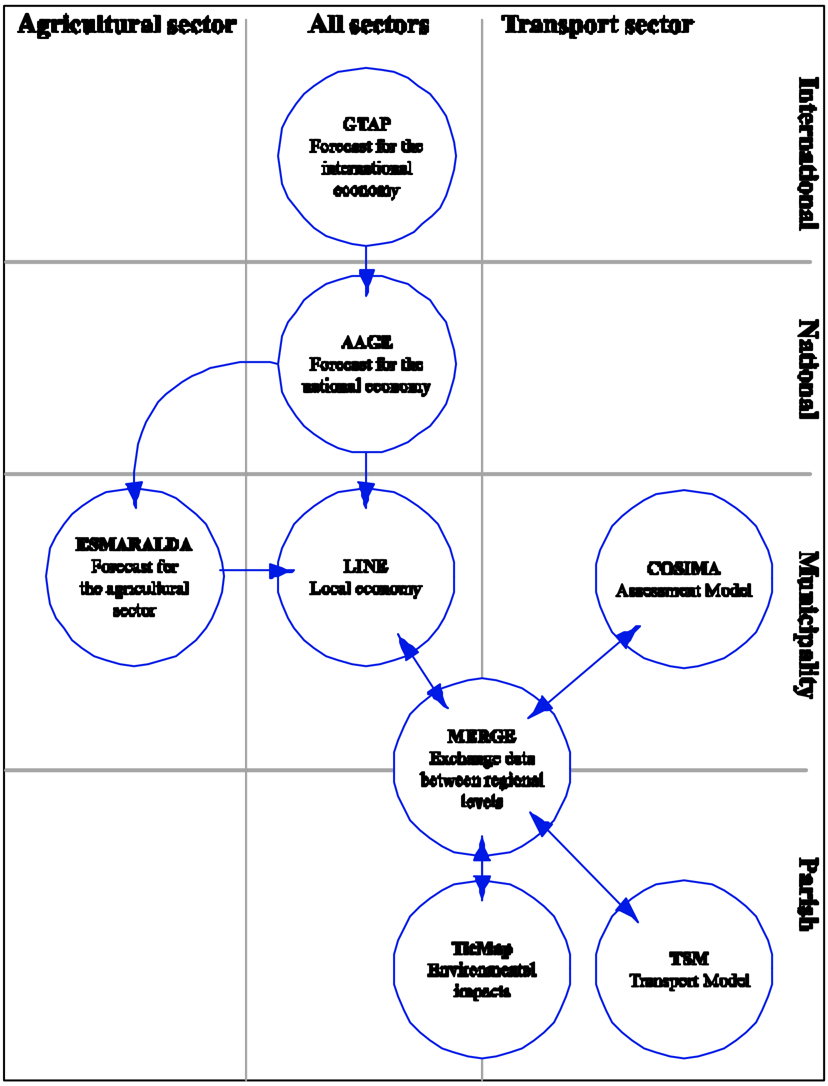
Hasler et al. (2002) present analyses of regional agricultural development and the overarching regional development. These analyses use sector models for agriculture (ESMERALDA) and general models (GTAP, AAGE and LINE). The results of the projection and consequential analysise for agriculture and the local economy are presented using a combined modelling system for international, national, regional and local development, including the interaction between agriculture and the rest of the economy at each of the levels mentioned.

Madsen et al. (2007) describe an overall modelling system comprising the following subsidiary models.

As figure 3 shows, the model system describes the international, national, regional (municipal) and local levels vertically and describes the sector disaggregation of the modelling system horizontally.

Madsen et al. (2007) use the modelling system to illustrate the regional consequences of road pricing. The analysis includes the use of transportation models to illustrate the consequences for transportation costs caused by introducing road pricing. Based on these factors, the local economic consequences of changed transportation costs are calculated using LINE.

Figure 3. Linking Danish models of different types and levels



8.2. Deliberations concerning the structure of a modelling system

A presentation of the modelling system includes deliberations about how to compose a modelling system on the basis of the issues to be analysed. The interaction between regional development and transportation is used as a case in point to illustrate the problems involved.

Various standard configurations of modelling systems are set up:

a) expansion of sector models;
b) expansion of regional and sub-regional models;
c) loosely connected models; and
d) fully integrated models.

The first approach can be illustrated using transportation models whose point of departure in developing the model is the transportation issue, i.e. the subsequent focal point of regional and local development analyses. Expanding sector models as a method is cautioned against, as this can entail a risk of bias towards exaggerating the sector's significance.

The second approach, which is solely based on general economic models, can be illustrated with analyses of regional effects of the traffic infrastructure. Even though the shift in inter-regional trade, commuting, shopping, etc., is important to traffic trends, it is undoubtedly necessary to include analyses of a more technical traffic-related nature, such as the choice of mode of transportation, route, etc., to achieve a complete picture of the consequences for transport flows and transportation costs and, thus, the consequences for the regional economy.

The third approach is based on the practical analysis situation where general economic and sector-specific models are often available for illustrating the effects on regional development and transportation. The specific models to be included in the analyses must be considered, including how the models should interact with each other.

Finally, there are fully integrated modelling systems where the model uses common basic data and the model is solved inclusively, and it is assumed that the subsidiary models have the same theoretical point of departure and that the solution represents a complete, balanced system.

8.3. Loosely connected systems

As the loosely connected systems currently serve as the point of departure for the practical planning situation, it is important to take a closer look at the choices taken for setting up a system such as this.

A central issue is the reciprocal hierarchy involving the subsidiary models to be identified. In this respect, the relationship between a sector model and a general economic model is described as an ex ante model, an ex post model or a simultaneous approach. Madsen et al. (2007) seek to establish a simultaneous calculation procedure so that the transportation model and the local economic model perform a number of calculations to find a combined simultaneous equilibrium. The actual result was that the model calculations were only used in the ex ante model approach. This was due to the project's limited resources and the unavoidable difficulties of describing the consequences leading from the general regional economy to the transportation sector.

The "ex ante model approach" uses the transportation model as its ex ante model, which calculates the generalised transportation costs (with and without road pricing). The transportation costs are then used as input in the general local economic model,[35] which on the basis of modifications in the transportation costs calculates the impact of costs and prices subsequently affecting the quantity model's determination of demand, production, income and employment.

8.4. Perspectives

Integrated modelling systems are the most satisfactory solution in the long term. Offhand, this appears to be an insurmountable task as it would require huge data processing systems and extremely complex modelling systems that are difficult to solve. Without going into detail, the introduction of micro-simulation models, which includes the modelling of (a wide range of) decisions for individuals and production units at a micro level, seems to be a realistic solution in order for it to be possible to model a local economy in its entirety in the future.

[35] The details are presented in the article and in subsequent sections of this summary.

C. Regional Data and the General Local and Interregional Social Accounting Matrix

In the same way that local models include a unique description of economic activity, from an international research perspective, the local national accounting matrices, which the models use as the basic data, include an unprecedented description and degree of detail. Similarly, the principles used in setting up the national accounting matrices are a unique contribution to efforts in this area.

9. Spatial Accounting Methods and the Construction of Spatial Social Accounting Matrices[36]

Regional and local economic analyses use data for delimited analyses of individual issues and for analyses focusing on the overall effects on the local economy. The data are available as isolated, autonomous sets of data or are organised into local social accounting matrices or national accounting matrices.

Besides obtaining a broad perspective on a local economy, the purpose of integrating data into local social accounting matrices is to ensure the quality of the data, e.g. by ensuring the compliance of accounting identities. Accounting identities must be fulfilled for individual units (producers and households) at a meso level (e.g. it must be true that the sum of interregional exports equals the sum of interregional imports) and at a macro level (the total supply of a commodity equals the total demand). If the consistency of autonomous sets of data is not verified during the data setup, there is a risk of drawing incorrect conclusions because the data are not comparable or do not "correspond" if collated.

9.1. Background

The task of setting up national accounting matrices has been going on in Denmark for thirty-five years. The first attempts were made for Southern Jutland (Damgård et al. 1983). Regional accounting matrices were subsequently set up for all counties (Ahmt & Madsen 1997).

In the mid-1990s, it became technically possible to set up social accounting matrices for municipalities, which occurred through a joint effort involving the Danish Institute of Governmental Research and Statistics Denmark. These efforts are documented by Madsen et al. (2002b)[37] and Madsen & Jensen-Butler (2005). SAM is now used as a database for Denmark's political regions, employment regions, etc., as part of a monitoring model where data concerning local production, etc., are used as a basis for assessing economic development at a local level.

9.2. The two-by-two-by-two principle

The underlying principle of the local social accounting matrix (SAM) is the "two-by-two-by-two principle". The principle is also used in working with the general interregional quantity and price model and is illustrated in Figures 1 and 2.

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[36] Madsen, Bjarne and Chris Jensen-Butler (2005): Spatial Accounting Methods and the Construction of Spatial Accounting Matrices. *Economic Systems Research, vol. 17, no. 2, pp. 187–210.*

[37] Section 4 of Madsen et al. (2002b) includes Statistics Denmark's documentation of efforts to set up production figures broken down by municipality.

First of all, the local social accounting matrix for economic activity includes two agents, i.e. producers (Pj) and institutions (Rh). SAM includes the principle of micro registration of economic activities in terms of production units and households (institutions).

Second, the local economy includes two markets: the commodity market and the factor market. SAM includes the principle of micro registration of production and demand for commodities and income (and employment), respectively, for types of factors of production.

Third, supply and demand are geographically linked in these two markets. The factor market involves commuting while the commodity market involves trading and shopping.

9.3. Methods of data collection and calibration

SAM includes a mixture of bottom-up and top-down data. *Bottom-up data* is based on register data and administrative data or total counts which are subsequently summed up for macro-data in the local social accounting matrix. These data are for the *factor market*, i.e. the production sectors' demand for factors of production and the households' supply of factors of production. The sectors' demand for factors of production is classified according to sector and type of factor of production and grouped with the place of production. The households' supply of factors of production is classified according to types of families and types of factors of production and grouped with the place of residence.

Top-down data use a combination of a balanced national accounting matrix for the entire country, production data for local areas and sundry surveys for local economic activity in the local area. Top-down data use estimated figures for supply of commodities (covering production and imports from abroad) and demand of commodities (covering local demand and exports abroad). Estimations of production broken down by sector and commodity use of local production data calculated according to place of production and national data for the production broken down by sector and commodity. Imports from abroad are estimated on the basis of data for local demand broken down by commodity and national import percentages.

The estimation of demand includes data from Statistics Denmark concerning the production sectors' intermediate consumption, register data concerning disposable income and survey data concerning private consumption, data concerning local production of public-sector services for use in estimating governmental expenditure and investments, whereas the estimation of exports abroad uses national export data (broken down by commodity) and production data.

As the quality of register data is assumed to be excellent, only the commodity balance is reconciled, while the factor balance is the point of departure for estimating the commodity balance. The commodity balance is based on the national commodity balance.[38] Madsen & Jensen-Butler (2005) present the local commodity balance which is subsequently divided into a balance of payments and then subdivided into a commodity balance, commuting balance, shopping and tourist balance and public-sector balance.

9.4. Perspectives

Using the bottom-up approach for both the factor and the commodity market based on register data will be commonplace in the future. Using register and administrative data combined with

[38] The national commodity balance is set up in so-called influx and use tables where the national influx is reconciled with national use.

total counts for the factor market, which occurs in setting up SAM, is thus the first step towards setting up an entire national accounting matrix on the basis of register data. Whereas the local national accounting matrix is currently reconciled solely in terms of the commodity balance, a system that uses register data for both the factor balance and the commodity balance will have to be reconciled differently. In this case, it cannot be automatically assumed that there are errors in the estimation of the commodity balance – and that, as a result, the factor balance and the commodity balance will have to be adjusted.

10. Make and Use Approaches to Regional and Interregional Accounts and Models[39]

As register data, administrative data or total counts do not exist for all areas, the need has arisen to develop and use working principles for creating SAM which ensure that data meet basic consistency requirements and working methods, to ensure a higher data quality even when specific micro-level observations do not exist. It is argued in ***Section 10*** (see Madsen & Jensen-Butler 1999b) that the estimation of data in a local accounting matrix should be performed at the greatest level of detail and should use identities for supply and demand for commodities to ensure that data comply with basic accounting restrictions.

Jensen-Butler et al. (2003) analyse the quality of different procedures for estimating intra-regional and interregional trade, and their analysis indicates that a disaggregated[40] procedure secures higher quality data, if the trade structure for given commodities/groups of commodities is very localised, i.e. commodities are supplied between municipalities in a local area whereas no significant quality gains are available if the trade pattern for the given commodities/groups of commodities is interregional or international.

[39] Bjarne Madsen and Chris Jensen-Butler (1999): Make and Use Approaches to Regional and Interregional Accounts and Models. *Economic Systems Research, vol. 11, no. 2, pp. 277–299.*

[40] A disaggregated procedure for estimating regional trade data consists of utilising municipal data for influx and use, after which the trading pattern at a regional level is aggregated on the basis of this. In contrast, only regional data are included in an aggregated procedure where trade data are estimated at a regional level without taking into account that detailed data are available at a municipal level.

D. Regional Consequences of Transportation Investments and Regulation

A central aspect of the model development process has originated in analyses of the regional and local consequences of transportation investments and, most recently, the regulation of the transportation system, e.g. road pricing. In the projects carried out in the 1990s, the effects of the three fixed links (Great Belt, Øresund and Fehmarn Belt) were naturally in focus. The point of departure was thus a combination of, on the one hand, political and administrative wishes to obtain information about the anticipated regional and local effects of these large-scale projects and, on the other, research-related interests in developing analytical instruments for understanding the interaction of transportation investments, on the one hand, and regional and local development on the other.[41] Over the past decade, the primary wish has been to obtain knowledge about the effects of regulating the transportation system and road pricing in particular.

The following presents a review of the analysis results, the structure of the model(s) used in the respective analyses and the interaction between results and model structure.

11. Modelling the Regional Economic Effects of the Danish Great Belt Link[42]

The regional consequences of the Great Belt Link are analysed in various reports and articles (Madsen 1992; Madsen & Jensen-Butler 1991, 1992; and Jensen-Butler & Madsen 1996/ 2004). The total effects are estimated to be approximately 2,000 jobs. Greater Copenhagen, West Zealand and Funen (all of which are connected by the Great Belt Link) achieve the greatest gains, whereas peripheral regions viewed in relation to the Great Belt Link (particularly North Jutland County, which has achieved virtually no transportation gains on the Kattegat routes) achieve no benefits. The limited effect should be seen in the light of the model used in the analysis (AIDA) and the effects included in the analysis.

The analysis presented is an ex ante analysis showing the predicted effects before the link was established. The analysis studies the effects on regional competitiveness and includes the effect on regional exports and imports, whereas other effects – such as the consequences of discontinuing the ferry traffic across the Great Belt and rerouting the flow of traffic from the Kattegat routes to the Great Belt Link ("traffic corridor effects") – are not included in the analysis. The AIDA model (Madsen 1992) which is used and set up as part of the analysis, is an "Isard" type of interregional quantity model where the regional input-output model is institutional, i.e. sector-by-sector.

$$q = M(A_{i,j}^{R,S}, F_{i,j}^{R,S}, eu_i^R)$$

where

$A_{i,j}^{R,S}$ *is sales from sector i to sector j from region R til region S*

$F_{i,j}^{R,S}$ *is sales from sector i to final demand component j from region R to region S*

eu_i^R *is exports to abroad from sector i to region R*

[41] Madsen et al. (1993) review of foreign studies of the regional consequences of transportation investments.

[42] Jensen-Butler, Chris and Bjarne Madsen (1996, 2004): *Modelling the Regional Economic Effects of the Danish Great Belt Link*, Papers in Regional Science: The Journal of the RSAI, 75, 1: pp. 1–21 and in: *Classics in Transport Studies*. Edward Elgar, UK.

AIDA is based on 12 regions, 6 sectors and 7 components of final demand. In AIDA, trade among regions is calculated for sectors, i.e. the input-output model establishes a connection between production values for regions and sectors, on the one hand, and the demand for raw materials ($A_{i,j}^{R,S}$) and final demand ($F_{i,j}^{R,S}$) for regions and sectors, on the other. Trade between regions is assumed to be influenced in the same manner as international exports, i.e. calculated with the foreign-trade elasticities used in the national model at that time. Given the fluctuations in interregional exports, international trade is estimated using a double constrained gravity or entropy maximisation model where trade flows are estimated as a function of transportation costs. The model is calculated using the gravity model and includes the redistribution of interregional exports and the interregional trade pattern which arises because domestic transport costs fall after the opening of the Great Belt Link.

AIDA has several shortcomings which limit the validity of the results presented. First of all, the effect of modified transportation costs on the prices of finished commodities should be integrated into AIDA. Secondly, Isard's interregional input-output quantity model should be replaced by a model based on the principles of the general quantity model where interregional trade is modelled in commodities. Finally, several other effects should also be included, such as the impact of discontinuing the ferry traffic across the Great Belt Link and traffic corridor effects, but also the long-term impact on inventories and logistics and relocation patterns.

12. An Eclectic Methodology for Assessment of the Regional Economic Effects of the Fehmern Belt Link between Scandinavia and Germany[43]

The regional consequences of a fixed Fehmarn Belt Link are analysed in various reports and articles, particularly Cnotka et al. (1994); Madsen & Jensen-Butler (1999a & 2003) and Jensen-Butler & Madsen (2000). The characteristic feature of the fixed Fehmarn Belt Link is that it is international, in contrast with the fixed Great Belt Link, whose primary importance is domestic. The fixed Fehmarn Belt Link connects two metropolises (Copenhagen and Hamburg) and passes through a border area between Denmark and Germany typified by low economic activity and weak economic growth. The first analysis shows a virtual balance between the gain and loss of jobs, because the competitiveness gains from an employment perspective are all but offset by the loss of jobs caused by the discontinuation of ferry traffic. The loss of jobs is particularly prevalent in Storstrøm County and the East Holstein district (Cnotka et al. 1994; Jensen-Butler & Madsen 2000) because at the time of the studies there were a large number of people employed in the ferry operations. Subsequently, updated analyses (Madsen & Jensen-Butler 1999a) show a decline in the number of jobs lost because the importance of ferry traffic to employment declined concurrent with the introduction of new ferry technology. The link would significantly benefit Greater Copenhagen, especially because Greater Copenhagen could benefit from establishing high-speed trains to Hamburg and the rest of the European mainland.

The methodology of the Fehmarn Belt analyses (ex ante) differs from the Great Belt analyses by involving more effects and taking a simpler approach to the analysis of the effects on competitiveness. First of all, the analyses examine the significance of the transition from ferry operations to a fixed link – and the economic consequences of derivative economic activity,

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[43] Jensen-Butler, Chris, Bjarne Madsen (2000): *An Eclectic Methodology for an Assessment of the Regional Economic Effects of the Fehmarn Belt Link between Scandinavia and Germany*. Regional Studies, Vol 33.8, pp. 751–768.

such as hotel and transportation services and the impact on competitive ferry routes. Secondly, the analyses examine the effects on international competitiveness for all of Europe, whereas the Great Belt Link analysis solely focused on the impact of the relative competitiveness among the counties of Denmark.

Consequently, different modelling instruments were used:

- a traffic model for traffic between Scandinavia and the European mainland;
- a regional model for economic activity in Storstrøm County (EMIL);
- an interregional model for Danish counties (AIDA); and
- an potential model for illustrating changes in competitiveness for various regions in Europe.

This set of models was used for calculating the regional and local consequences of production, income and employment of the following:

- replacing the ferries with a fixed link (EMIL);
- rerouting corridor traffic from Sweden's Baltic routes and the Jutland corridor to the Fehmarn Belt corridor (traffic model);
- heightened level of activity in the accommodation and restaurant sectors (traffic model and EMIL, respectively); and
- improved and impaired accessibility for various regions of Scandinavia and the European mainland (potential model).

The analyses' approach is summarised as eclectic because it was not possible, for data-related and technical-modelling reasons, to set up a comprehensive model for the national and international effects of a fixed Fehmarn Belt Link as regards regional competitiveness.

The analysis is a methodological improvement because several effects are included, e.g. the effects of discontinuing ferry operations and corridor effects. In terms of modelling, the analysis is status quo, as AIDA is used as a frame of reference where the consequences of modified transportation costs are not integrated into the interregional model, and the interregional input-output quantity model is Isard-based, which involves theoretical difficulties.

Neither the Great Belt nor the Fehmarn Belt links was analysed by performing ex post calculations. The methods for model-based decomposition of the effects of traffic facilities have been reviewed for the Øresund Link (Madsen 2000; Madsen & Jensen-Butler 2001). This describes how (interregional general equilibrium) models can be used for ex ante and ex post evaluations of the fixed Øresund Link. The methodology was used in analyses of regional development (Madsen & Jensen-Butler 2002; Jensen-Butler & Madsen, 2005). In spite of the fixed links' great impact on economic development, research into the significance of the links has not been carried out ex post (all three links) or ex ante (the Øresund Link).

13. Modelling Transport in an Interregional General Equilibrium Model with Externalities[44]

A central theme in the last decade or so has been the effects of road pricing. An initial study of the regional consequences of road pricing involves the effects of making transit across the

[44] Larsen, Morten Marott, Bjarne Madsen and Chris Jensen-Butler (2007): "Modelling Transport in an Interregional General Equilibrium Model with Externalities" in: *Regional Externalities*, Wim Heijman (ed.).

fixed Great Belt Link free of charge (Madsen et al. 2003 and Madsen & Jensen-Butler 2004a), i.e. road pricing in reverse. In this analysis, the prices for commodities and services are reduced by about 0.2% which affects the price of exports abroad. Rising exports abroad and falling imports from abroad lead to a growing demand and production with a total increase of almost 6,000 jobs. The analysis also studies the effect of financing the expenditure of providing free transit through income taxes, which would reduce demand and production and thus jobs by just short of 2,000, for a net effect of free tax-funded transit of approximately 4,000 jobs. Regionally, free transit would have the greatest impact on Greater Copenhagen and the counties of West Zealand and Funen, while North Jutland would incur a relative loss.

Another study of regional consequences shows that introducing road pricing for lorries (Madsen et al. 2003) would affect the cost of transporting commodities and services. As a result, the prices of exports in the four scenarios increase by 0.2–0.6%, depending on whether the charge is introduced abroad only or also in Denmark. Falling exports, etc., lead to a loss of 1,500–3,000 jobs.

The new analyses all use the LINE model. Whereas the transportation effects in the AIDA model were exogenous, the transportation cost changes are included in LINE's price model. In AIDA, exports abroad or to other regions change exogenously because of the reduction in transportation cost which affects the prices of the regions' exports/imports and thus the exports to and imports from abroad and the regional trade pattern (modelled in a gravity or entropy maximisation model). The transportation-cost changes are included in LINE in the overall price formation process. As described in ***Section 5***, the regional and local costs and prices are formed in a chain calculation where cost changes are passed on to the next link in the production chain, ending up at the end-user (domestic final use or exports abroad). A reduction of transportation costs resulting from free transit across the Great Belt Link or increased transportation costs by means of road pricing for lorries or people affects the commodity prices in an upward and downward direction, respectively. These effects are passed on to the next link in the production chain, which in turn passes them on to the next, and so on. The overall effects of this are numerically calculated in LINE, but are illustrated by the solution for the general interregional price model (***Section 5***).

Section 13 (Larsen et al. 2007) presents the results of an analysis of the regional effects of road pricing for passenger cars. This analysis includes LINE's quantity and price model in the standard version described above and with the addition of externalities. First of all, the effect of "urban externalities" is included, i.e. the factor that, other things being equal, proximity to an urban centre increases the earnings per employee. Secondly, "pecuniary externalities" are included, based on the assumption that the wage is higher the greater the distance from the workplace. Both externality relationships were estimated by Morten Larsen and are included in Larsen et al. (2007) for calculating the regional consequences of road charges.

The analysis shows that the average transportation costs are expected to increase by 5–10%, mostly in regions predominated by the use of cars within the region's own urban area (intraregional transportation) and least if the transportation takes place in peripheral districts outside of urban areas. These distribution effects reflect the fact that road pricing is greatest in urban areas and lowest in rural areas and that the road pricing has the most weight in areas with a high percentage of car ownership and lowest in urban areas with short transportation distances. As result, a pattern emerges in which traffic in urban centres in Copenhagen and Århus pays low road charges, whereas suburban traffic, particularly in Greater Copenhagen, pays high road charges and traffic in rural and peripheral areas pays low road charges.

Calculations without externalities result in relatively higher price rises for production and exports for regions with high road charges and lower price rises for urban centres. The effects on prices for private consumption, calculated according to place of residence, are greatest in areas where shopping involves relatively high road charges (e.g. suburban areas of Greater Copenhagen) and less in areas with lower road charges. The result of this is that a total of around 8,400 jobs are lost, if externalities are not taken into consideration.

If, in addition to this, it is assumed that increased transportation costs result in fewer urban externalities and a greater wage pass-on effect, the loss of jobs increases to around 12,600. The model calculations show that the effects of adjusting wages in the event of higher transportation costs will particularly lead to lower economic activity (approx. 2,900 jobs) compared to the effects of reduced urban externalities (approx. 1,300 jobs).

14. Teleworking and Transport: Modelling the Regional Impacts in an Interregional General Equilibrium Model with Externalities[45]

Another use of LINE in the transportation area is the relation between regional development and teleworking. In this context, "teleworking" is defined as work performed at home using information and communications technology (ICT). In ***Section 14,*** the regional significance of teleworking is modelled, which involves technical modelling calculations of the loss of jobs by removing teleworking – in reverse.

The direct regional effects are divided into 1) the direct effects on demand, originating from the direct reduction in commuting costs from teleworking; 2) the labour-market expansion effect resulting from an increased potential for teleworking which expands the geographic labour-catchment area; and 3) the productivity effect of teleworking comprising the fact that working at home is potentially more productive than working at the place of work.

Teleworking is regarded as a substitute for commuting which can be carried out using different modes of transport. Each mode of transport represents a different degree of usefulness for different road-users. The most important aspect in this context is that teleworking represents a time saving which can be used in various ways to benefit from other use. In addition, teleworking usually leads to a reduction of transportation costs as well. Hole et al. (2004a) estimate the percentage of teleworkers, which is highest among people with a high education, high-income groups, segments without managerial functions, etc. This percentage is used as the point of departure for determining the number of full-time teleworkers (almost 20,000) and their regional distribution. As the level of education and income is highest in Copenhagen, it naturally follows that the percentage of teleworkers is highest in Copenhagen. A reduction in commuting costs is estimated on the basis of this, from which a reduction in the disposable income of almost DKK 200 million is derived.

The labour-market expansion effect – or the positive externalities of reduced transportation costs – is estimated using the same technique as in Larsen et al. (2007). An increased potential for teleworking reduces the actual transportation distances, which reduces the actual wage,

[45] Bjarne Madsen, Arne Risa Hole, Chris Jensen-Butler, Morten Marott Larsen and Lasse Møller-Jensen (2007): *Teleworking and transport: Modelling the regional impacts in an interregional General Equilibrium Model with externalities.*

which in turn reduces the price of the export, increases exports and thus production, income and employment.

The productivity effect of "no teleworking" can be estimated on the basis of Hole et al. (2004b) who estimated a bell-shaped productivity curve for the scope of teleworking. The productivity curve shows that the average productivity working at home is high and increases until the maximum gain of teleworking is achieved. After this the average productivity of teleworking continues to decline for additional days of working at home. The bell-shaped curve takes into account the "peace and quiet" advantages in the first days of working at home, but the loss from insufficient contact with co-workers after a certain extent of teleworking reduces the value of further teleworking. Increased average productivity from teleworking reduces the production costs per unit produced, which lowers the prices, including export prices, which increases exports, and thus production, income and employment.

The overall employment effect is calculated at around 250 jobs – highest in Copenhagen and lowest in peripheral areas. First of all this reflects a generally low teleworking percentage. Secondly, it reflects the fact that the largest percentage of teleworkers are in Copenhagen where the level of education and income is highest.

15. Regional Economic Impacts of Traffic Regulation on Tourism: The Case of Denmark[46]

A final example on the application of regional models in the analysis of the impacts of regulation of transport activities is the fixed Great Belt Link free of charge case on tourism activities. The analysis shows very limited impacts on regional economic activities: Number of jobs increases with approximately 200, which is concentrated to the beach regions in the western part of Denmark. But despite the seemingly small impacts, the changes in the geographical pattern of choice in travel destination can be substantial, and can in this way have important implications for the volume of traffic and the environment. Because the costs of passing the fixed Great Belt Link is a non-neglectable share of total transport costs for the journey to the tourist destination, and the transport costs for the price of the tourism product are important – for example for families living in Copenhagen and going on a beach holiday on the west coast in Denmark – a reverse road pricing can make it attractive to change tourist destination and to travel longer implying increasing traffic and negative environmental impacts of tourism. And this aspect is important in the efforts to reduce traffic and its negative impacts on the environment.

In this article the structure of the sub-model in LINE for private consumption is presented: In LINE the private consumption is divided into tourism consumption and local private consumption. Tourist consumption is in turn divided into night tourism and one-day tourism. The night tourism is subdivided by type of night. Both for tourism and local private consumption the origin or the place of residence of the consumers enters into the model. Tourism is divided into Danish and foreign tourists, which are divided by nationality and place of residence. In LINE foreign tourist consumption is modelled on the basis of number of nights and the daily consumption, whereas the domestic tourist consumption is modelled at the place of residence

[46] Madsen, Bjarne, Chris Jensen-Butler and Jie Zhang (2003): The regional impacts on tourism of traffic regulation. The case of Denmark. *Urban & Regional Development Studies*, May 2003.

on the basis of disposable income and on tourist consumption share of the total private consumption.

In LINE the prices on different tourist products are modelled, which among other factors depend upon the transport cost from the place of residence to the tourist destination (the place of commodity market). In the analysis the prices on tourism activities in a region are partially determined by the transport cost. In the case of the fixed Great Belt Link free of charge the prices are reduced for the region, where tourists use the fixed Great Belt Link as a necessary link to the destination. By assuming that numbers of nights depend upon the relative prices of the tourist destinations, the change in tourist consumption is modelled (cf. Jensen 1998). Finally, LINE gives the impacts in terms of production and number of jobs both directly and derived.

16. Conclusion

Setting up the general interregional model is the central part of the study and contributes to understanding the regional and local economy. Whereas regional analyses solely describe economic activity within the region as a whole and the economic interaction among the regions, the local model expands the analysis of economic activity in local areas within a region, just as the model qualifies the understanding of the economic interaction among local areas and regions to the extent that the interaction crosses regional boundaries.

The general interregional model is theoretically formulated and its analytical solution is presented. The general interregional model uses the "two-by-two-by-two" principle which is central to the doctoral dissertation. The two-by-two-by-two principle is based on the fact that the local economy has two types of agents (producers and institutions), two markets (the factor market and the commodity market), and a geographical origin and destination for all flows of supply and demand. Consequently, the study is based on four geographic concepts (place of production, place of factor market, place of residence and place of commodity market) and four social accounting concepts (sectors, types of factor of production, types of institution and types of commodity).

The model is set up in terms of changes so that the general interregional model can be used for analysing the effects of alterations in the local and regional economy, e.g. regional and local consequences of demographic changes.

The study presents the LINE model, which is used as a local economic model and is based on the principles of the general interregional model. A number of uses are presented, from projections to consequence analyses, some of which are ex ante and others are ex post calculations. The underlying principles of a local national accounting system (SAM) which is used in LINE, etc., are presented, and the analyses of sound working principles, e.g. as regards level of aggregation in SAM, are reviewed.

In this light, a conclusion should naturally refer to the future. An obvious trend in this regard is the empiric potential for micro-based analyses, which is growing rapidly. In terms of data, a substantial part of SAM is micro-based (data concerning income and employment for people). The next step is obvious and includes micro-data concerning the supply and demand of commodities. As a natural consequence, the local national accounting matrix – based on the two-by-two-by-two principle – is set up as a whole on the basis of micro data, after which verification procedures at micro, meso and macro levels ensure compliance with the basic accounting identities.

With regard to modelling, micro-simulation models appear to be the next step in improving the general interregional model: micro-simulation of decisions at a micro-level (producers and institutions) followed by modelling in the general interregional quantity and price model for ensuring equilibrium requirements concerning the micro, meso and macro levels, appears to be a natural, necessary development in the field of regional and local economic research. In this context, the author of the doctoral dissertation has formulated "the general regional micro-simulation model" in a project application submitted to the Research Council for Business and Society. The development of this model is in its infancy, however, and is therefore not included in this doctoral dissertation.

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Section 1:

Sammenfatning

1. Sammenfatning

1. Indledning og baggrund

I denne sammenfatning præsenteres hovedresultaterne i afhandlingen. Samtidig gives oversigt over forarbejder til afhandlingens enkelte afsnit.

Afhandlingen består af fire hovedafsnit. I ***hovedafsnit A*** sammenfattes analyser af den regionale og lokale udvikling i Danmark fra 1980 og fremefter (afhandlingens afsnit 2 og 3). ***Afsnit 2*** indeholder en empirisk beskrivelse af udviklingen i geografisk samling eller spredning af den økonomiske aktivitet (koncentration kontra dekoncentration) og udviklingen af forskelle i gennemsnitsindkomst (konvergens kontra divergens). Resultater af fremskrivninger af den regionale økonomi (koncentration og dekoncentration) med et samlet modelsystem for dansk regional og lokal økonomi[1] præsenteres. ***Afsnit 3*** indeholder en dekomponering af den økonomiske udvikling (koncentration henholdsvis dekoncentration) i forklarende faktorer. Den lokaløkonomiske model LINE anvendes i dekomponeringen, ligesom principielle metodemæssige spørgsmål i forbindelse med dekomponering præsenteres.

I ***hovedafsnit B*** præsenteres den generelle interregionale model. Med generel menes, at modellen bygger på generelle dimensioner i lokale økonomier, dels geografiske (produktionssted, bopæl, faktormarkedssted og varemarkedssted) dels faglige (erhverv, husholdningstyper, produktionsfaktorer og varer). Disse dimensioner er gældende for alle lokale områder, som indgår i en markedsøkonomi og benævnes 2 x 2 x 2-princippet. I ***afsnit 4*** præsenteres den generelle interregionale mængdemodel, som beskriver mængden af økonomiske aktivitet i et lokalområde, dvs. produktion, indkomst, beskæftigelse mv., og mængden af samspil mellem lokalområder, dvs. handel, pendling, shopping mv. I afsnittet præsenteres mængdemodellens løsning. Mængdemodellens struktur benyttes som udgangspunkt for en klassificering af lokaløkonomier i forhold til deres lokaløkonomiske funktion. I ***afsnit 5*** præsenteres den generelle interregionale prismodel. I prismodellen indgår bestemmelsen af omkostninger, priser og nominelle indkomster i lokalområder. I afsnittet præsenteres modellens løsning, og prismodellens struktur benyttes som udgangspunkt for klassificering af lokalområders økonomi i forhold til deres konkurrenceevne. Endelig præsenteres en samlet simultanløsning af mængde- og prismodel under forudsætning af et enkelt link mellem eksportpriser (prismodellen) og eksportmængder (mængdemodellen). I ***afsnit 6*** omformuleres mængde- og prismodellen til belysning af demografiske forandringers betydning for den lokale økonomi – især den voksende ældrebefolkning i udviklede lande. For at belyse aldringens betydning for strukturen i produktion, efterspørgsel, indkomst og beskæftigelse opskrives den generelle interregionale mængde- og prismodel i differens. De to submodeller løses analytisk, og der redegøres for, hvorledes de lokale økonomier tilpasses på kort, mellemlangt og lang sigt. I ***afsnit 7*** præsenteres LINE, som er en lokaløkonomisk model for danske kommuner. Strukturen i LINE følger i høj grad den generelle interregionale model, men afviger på en række punkter, som afspejler datamuligheder og behovet for at reflektere den underinddeling af økonomiske beslutningstagere, som indgår i en (dansk) lokal økonomi. 10 forskellige anvendelser af LINE præsenteres. Hver version af LINE er konfigureret på forskellig måde, dvs. den geografiske aggregering er forskellig (amtsmodel, kommunemodel, oplandemodel, subkommunal model), ligesom aggregeringen er forskellig med hensyn til erhverv (turismeerhvervsmodel, fødevareerhvervsmodel, transporterhvervsmodel, offentlig sektormodel osv.), varer (turismevarer,

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[1] Modelsystemet består af en model for den internationale økonomi (GTAP-modellen), en national model for dansk økonomi (AAGE-modellen), en regional model for landbrugsproduktion (ESMERALDA) og en interregional model for danske kommuner (LINE)

fødevarer, transportvarer, offentlige varer osv.), typer arbejdskraft (kønsopdelt, aldersopdelt, uddannelsesopdelt osv.) og typer husholdning (gift/ikke-gift, børn/ikke børn osv.). I ***afsnit 8*** præsenteres en analyse af de regionale konsekvenser af indførelse af roadpricing i Danmark. I analysen anvendes LINE, og det beskrives, hvorledes LINE indgår i et samlet system af modeller: En international generel ligevægtsmodel til modellering af den økonomiske udvikling (GTAP), en national generel ligevægtsmodel til modellering af dansk økonomi (AAGE), en interregional generel ligevægtsmodel (LINE) samt en national transportmodel (landstrafikmodellen).

Herefter beskæftiger ***hovedafsnit C*** sig med data for lokale økonomier, især spørgsmålet om etablering af lokale nationalregnskaber. I ***afsnit 9*** præsenteres det såkaldte 2 x 2 x 2-princip som udgangspunkt for registrering af data for lokaløkonomisk aktivitet. Det beskrives, hvorledes dette princip omsættes i et lokalt samfundsregnskab for danske lokalområder/ kommuner, kaldet SAM-K. Datakilder og konkrete metoder til opstilling og estimation af SAM-K præsenteres. I ***afsnit 10*** præsenteres et system af varebalancer og regionale varestrømme for lokale økonomier, herunder disses estimation og aggregeringsniveau. Der argumenteres for introduktion af varer i lokale samfundsregnskaber, ligesom der argumenteres for beregningsmæssig detaljering og anvendelse af bogholderirestriktioner i estimationen af lokale samfundsregnskaber for at sikre høj datakvalitet.

I ***hovedafsnit D*** præsenteres forskellige modelbaserede analyser af regionale konsekvenser af infrastrukturprojekter og -regulering. I ***afsnit 11*** analyseres de regionale konsekvenser af etableringen af en fast forbindelse over Storebælt. I analysen anvendes AIDA, som er en interregional mængdemodel for Danmark. Effekterne af infrastrukturforbedringer modelleres ved anvendelse af elasticiteter for transportomkostningerne og dermed vareprisernes betydning for regionernes eksportkonkurrenceevne og samhandelsstruktur. Med udgangspunkt i eksportændringer og ændrede samhandelskoefficienter modelleres i AIDA den faste Storebæltsforbindelses betydning for regional produktion, indkomst og beskæftigelse og regional samhandelsstruktur. I ***afsnit 12*** analyseres de regionale konsekvenser af en fast Femern Bælt-forbindelse. I analysen inkluderes ud over konkurrenceevneeffekterne tillige effekter for beskæftigelse og indkomst af omlægning fra færgedrift til fast forbindelse og korridoreffekterne, dvs. betydningen for beskæftigelse og indkomst af omlægning af trafikken til Femern Bælt-korridoren fra de øvrige Østersø-/"Skandinavien-Kontinentet"-korridorer. For at udvide analysen og inddrage nye effekter anvendes en "eklektisk metode", som på grundlag af et miks af forskellige modeltilgange sammenfatter de bredere virkninger af en fast Femern Bælt-forbindelse. I ***afsnit 8*** præsenteres en analyse af effekterne af at gøre det gratis at benytte den faste Storebæltsforbindelse med anvendelse af LINE. I analysen beregnes konsekvenserne for varepriser af billigere transportomkostninger i forbindelse med interregional varehandel, shopping og turisme samt forbedret indkomst ved faldende pendlingsomkostninger. Ændringerne i omkostningerne og dermed i priser regnes videre i prismodellen i LINE, således at de samlede prisændringer fordelt på regioner, varegrupper, erhverv mv. fremkommer. Omkostnings- og prisændringer fastsættes således ikke eksogent som med AIDA (første Storebæltsanalyse), men endogent i prisdannelsesmodellen i LINE. Samtidig indgår en fuld udbygning af interaktion, dvs. interregional og international varehandel, shopping og turisme, mens pendlingen alene indgår med den indenlandske del. I beregningerne er endvidere indregnet effekterne af en skattefinansiering af at gøre det gratis at passere den faste Storebæltsforbindelse.

I ***afsnit 13*** anvendes LINE til en udbygget analyse af konsekvenserne af gratis benyttelse af den faste Storebæltsforbindelse. Ud over de beskrevne omkostnings- og prisvirkninger – jf.

analysen i afhandlingens ***afsnit 8*** – indgår desuden virkningerne på indkomsterne af reducerede rejseomkostninger. For det første viser økonometriske analyser[2], at jo højere pendlingsomkostninger jo højere indkomst. Hvis det bliver gratis at passere den faste Storebæltsforbindelse, falder de nominelle indkomster og priserne, hvilket betyder øget eksport og mindsket import. For det andet viser økonometriske analyser, at indkomsten pr. beskæftiget er højere jo mindre transportomkostning til de store bycentre (København, Århus, Odense, Aalborg). Disse positive effekter for indkomsten ved forbedret transportsystem er ligeledes indlagt i beregningerne, således at eksporten vokser og importen går ned i regioner, der får fordele ved gratis transport over Storebælt. I ***afsnit 14*** foretages analyser af betydningen af telearbejde for den regionale økonomi. I beregningerne med LINE er indlagt en model for sammenhængen mellem graden af telearbejde og produktivitet[3]. I ***afsnit 15*** gennemføres analyser med LINE af de regionale konsekvenser for turismeaktiviteter af at gøre det gratis at passere Storebæltsforbindelsen.

[2] Den økonometriske analyse er gennemført af Morten Larsen.
[3] Den økonometriske analyse er gennemført af Arne Risa Hole.

A. Den regionale og lokale udvikling i Danmark

2. Tendenser i den regionale udvikling i Danmark[4]

I ***afsnit 2*** sammenfattes i Madsen og Andersen (2003) tendenser i den regionale og lokale økonomiske udvikling i Danmark. Ser man på udvikling i levevilkårene, har Danmark i en meget lang periode fra Anden Verdenskrig frem til midten af 1990'erne haft konvergens, dvs. at forskellene i gennemsnitsindkomst har været faldende (Dilling-Hansen m.fl. 1997; Dilling-Hansen og Schmidt 1997; Groes 1997; Ekspertudvalget 1998[5]; Jensen-Butler m.fl. 2002; Madsen og Andersen 2003; Jensen-Butler og Madsen 2005). Siden midten af 1990'erne har spredningen i gennemsnitsindkomsten været uændret eller lidt voksende. Som noget ny påpeger Madsen og Andersen, at resultatet afhænger af, om der ses på den gennemsnitlige primære indkomst – dvs. indkomst før skatter og indkomstoverførsler – hvor tendensen har været mod divergens, eller om der ses på den gennemsnitlige disponible indkomst – dvs. indkomst efter skatter og indkomstoverførsler – hvor spredningen har været stort set uændret (Madsen og Andersen 2003; Jensen-Butler og Madsen 2005). Som noget nyt peger Madsen og Andersen på vigtigheden af velfærdsstatens funktion i den regionale omfordeling af indkomster.

I Madsen og Andersen inddrages spørgsmålet om spredning af den økonomiske aktivitet, hvor der – hvis der ses på "store regioner" eller pendlingsoplande – har været en klar tendens til dekoncentration eller spredning af de økonomiske aktiviteter op til 1990, mens der siden 1990 har været koncentration (Madsen og Andersen 2003; Pedersen 2005). Udviklingen frem til 1990 har været præget af udflytning af økonomisk aktivitet fra hovedstaden til Jylland. Siden 1990 har der været tale om koncentration, hvor hovedstaden har haft en vækst betydeligt over de øvrige regioner. Udviklingen ses først på folketallet og senere for primærindkomster og disponible indkomster.

Ses på spredningen inden for pendlingsoplande har der været en tendens til dekoncentration i hele perioden. Det afspejler dels den kraftige udflytning dels indflytning til bycentrene inden for København, Århus og de øvrige bycentre, som har kunnet konstateres gennem hele perioden. Der opstilles spredningsmål for befolknings- og indkomsttætheden såvel mellem pendlingsoplande som inden for pendlingsoplande, hvilket er nyt i dansk regionalforskning.

I ***afsnit 2*** sammenfattes resultater af fremskrivninger af den regionale økonomi til 2015 (koncentration og dekoncentration) og resultater fra en række forskellige scenarieanalyser:

[4] Afsnit 2: Bjarne Madsen and Anne Kaag Andersen (2003): *Tendenser i den regionale udvikling i Danmark*. Papir præsenteret på seminar i Indenrigs- og Sundhedsministeriet den 29. januar 2003.
[5] Bjarne Madsen var sekretær for ekspertudvalget og gennemførte en væsentlig del af beregninger til rapporten.

Tabel 1. Konsekvenser for lokal indkomst: Baseline, markedsbestemte scenarier og scenarier for politisk styring – Indkomst i alt

	Hoved-staden og større byer	Mindre byer og oplande til hoved-staden og større byer	Land-kommuner	Landbrugs-kommuner	Udkants-kommuner	Sårbare kommuner	Udsatte kommuner
Basisscenario	+	++	+/0	-	-	--	--
Markedsbestemte scenarier:							
Liberal scenario	+	++	+/0	--	--	-	-
Industri	0	++	0	-	-	--	--
Turisme	+	0	-	-	0	(++)	(+)
Politisk styring:							
Velfærds-scenario	0	+	++	-	0	--	--
Rekreativt/befolknings scenario	+	+	0	-	-	--	--
Miljøscenarier	+	+	0	-	--	-	-

Fremskrivningen, som for første gang i Danmark foretages for kommuner[6], viser, at især områder præget af produktion af avancerede industriprodukter og service viser økonomisk fremgang[7], mens der for områder med traditionel industriproduktion og produktion af landbrugsvarer forventes en svagere økonomisk udvikling[8] [9]. Fremskrivningen foretages med et modelsystem (Hasler m.fl. 2002; Madsen m.fl. 2007), som er opbygget i samarbejde med Fødevareøkonomisk Institut på Københavns Universitet og består af GTAP, som er en model for den internationale økonomi, AAGE, som er en national model for dansk økonomi, en regional model for landbrugsproduktion (ESMERALDA) og en interregional model for danske kommuner (LINE).

Fremskrivningen er en blandt en række fremskrivninger med regionale modeller. I Madsen m.fl. 1992) blev der foretaget fremskrivningen med AIDA, som var en interregional model for Danmark med amterne som geografisk enhed[10] (Madsen 1992). Fremskrivningen viste koncentration, dvs. kraftig vækst i indkomst og beskæftigelse i Københavns og Frederiksberg Kommuner, gennemsnitlig vækst i de traditionelle industriamter i Jylland, mens udkantsamter som Storstrøms og Bornholms Amter viste markant økonomisk tilbagegang. Hermed peges for første gang på muligheden for markant vækst i hovedstadsregionen efter hele tilbagegangsperioden i 1980'erne. Et alternativt scenario, hvor der var indlagt en trend svarende til en videreførelse af den positive udvikling, som de jyske industriamter oplevede i 1970'erne og 1980'erne, pegede på dekoncentration, dvs. en langt mere positiv udvikling for de jyske amter.

Arbejdet med fremskrivninger er fortsat, og fra 2005 og fremefter foretages løbende fremskrivninger med LINE på grundlag af nationale fremskrivninger med ADAM (Dam 1995). Disse fremskrivninger har haft fokus på udviklingen på arbejdsmarkedet. Fremskrivningerne

[6] I international sammenhæng er der tale om unik modeludvikling og -anvendelse, når der ses på modellens geografisk specificering, kompleksitet og teoretiske fundament.
[7] "Hovedstaden og større byer" og "Mindre byer og oplande til hovedstaden og store byer" markeres med "+" henholdsvis "++".
[8] Landkommuner og Udkantskommuner samt Sårbare kommuner og Udsatte kommuner markeres med "-" henholdsvis "--".
[9] I fremskrivningen ses på den kvantitative vækst, dvs. påvirkning i retning af koncentration henholdsvis dekoncentration.
[10] Det er første gang, at der i Danmark præsenteres fremskrivninger for alle amter med en interregional model.

er foretaget for østdanske kommuner (Lundtorp m.fl. 2005; Madsen og Lundtorp 2006), for nye kommuner (Christoffersen m.fl. 2006 og 2007) og er bl.a. opdelt efter køn, alder og uddannelse. Fremskrivningerne peger på større koncentration af arbejdspladser, både mellem og inden for pendlingsoplande. Udviklingen efter arbejdspladser viser en relativ kraftig vækst i Københavns centrum og de ydre pendlingsområder, mens de indre pendlingsområder i hovedstadsområdet får en svagere udvikling. Opgjort efter befolkningens bopæl viser fremskrivningen koncentration mellem pendlingsoplande og dekoncentration inden for. Det er en konsekvens af, at befolkningen pendler stadig længere. Udviklingen peger samtidig i retning af voksende behov for personer med videregående uddannelse, særligt inden for sundhed og undervisning.

Scenarieanalyserne (jf. tabel 1) inddeltes i "markedsbestemte scenarier" og "politisk styring". Under "markedsbestemte scenarier" sås på landbrugspolitikken, som primært bestemmes af udviklingen i fødevareefterspørgslen samt af aftaler mellem EU, USA og øvrige lande inden for rammerne af WTO (Hasler m.fl. 2002). Denne udvikling kunne resultere i en fuld liberalisering, hvilket forudsattes i *liberaliseringsscenariet*. I de senere år var der foretaget væsentlige ændringer i den fælles europæiske landbrugspolitik, på daværende tidspunkt Agenda 2000-reformen. På trods af, at de daværende ændringer havde været ganske omfattende siden liberaliseringsprocessen startede i 1992, så blev der stadigvæk ydet en betydelig direkte støtte til arealer og husdyr samt i mindre grad direkte miljø- og landdistriktstilskud. Den fælleseuropæiske landbrugspolitik var under pres om helt eller delvis at afvikle disse tilskud og understøttedes på daværende tidspunkt af den forventede udvidelse af EU mod øst samt af forbrugernes aftagende villighed til at finansiere et meget højt landbrugsbudget. I liberaliseringsscenariet sås på konsekvenserne for regional produktion, indkomst og beskæftigelse i landbrug, fødevareindustri og andre erhverv af ændringer i fødevarepriser til verdensmarkedsniveau mv.

Videre sås på industriens udvikling inden for rammerne af globalisering (Andersen og Christoffersen 2002). Den overlegenhed i evne til at skabe fremgang i arbejdsproduktivitet, som har kendetegnet landkommunerne gennem perioden fra 1980 til 1996, ser ud til at være gået tabt efter begyndelsen af 1990'erne sammen med skiftet i økonomiske konjunkturer. Hvis det viser sig som en mere langsigtet tendens, at den perifert lokaliserede industris produktivitetsoverlegenhed ikke kan opretholdes, kan det få afgørende konsekvenser for det regionale mønster for indkomster og beskæftigelse. For at illustrere sådanne konsekvenser blev foretaget en modelkørsel med LINE, hvor industribrancherne, der særligt kendetegner den perifere del af landet – de udsatte brancher – forudsættes over en tiårig periode at have en vækstrate for arbejdsproduktivitet, der ikke er højere end vækstraten for alle industribrancher under et. Selv om den gennemførte modelkørsel er simpel af udformning, anskueliggør den tydeligt, at det vil forrykke udviklingen i indkomster og beskæftigelse i retning mod landets centerområder, hvis de periferiorienterede industribranchers overlegenhed i evne til at udvikle arbejdsproduktiviteten går tabt som en mere varig tendens.

Endelig placeredes turismescenarier under markedsbestemt udvikling, idet det i høj grad baseres på udvikling i brugerefterspørgslen. Der præsenteres resultater for turismens betydning for produktionsværdi, indkomst og beskæftigelse fordelt på sektor og region. Herudover ses på turismens indvirkning på beskæftigelse og primærindkomst fordelt på kvalifikationsgruppe, køn og alder, på disponibel indkomst, på indkomstskat, på indkomstoverførsler og på vareskatter og handelsmarginaler osv. Desuden gives et eksempel på scenarioanalyser for turisme. De tre scenarier inkluderer 1) en stigning på 20% i udenlandsk overnattende turisme på Bornholm, 2) en stigning på 20% i udenlandsk endagsturisme i

Sønderjylland, 3) en stigning på 20% i dansk turisme i Ringkøbing. De detaljerede resultater præsenteres i hvert enkelt scenario med hensyn til turismens betydning for produktionsværdi, indkomst, beskæftigelse, privatforbrug, disponibel indkomst, overførselsindkomst, indkomstskat, moms, fortjenstmargin og interregional import og eksport.

Under "politisk styring" sås på regionale konsekvenser af statens finanspolitik (det såkaldte "Velfærdsscenario", jf. Dam m.fl. 1997), rekreative tiltag i kommuner og regioner (Andersen 2002) samt miljøscenarier i landbrugspolitikken (Hasler m.fl. 2002). I Velfærdsscenariet ses på den regionale betydning af to scenarier af offentlig finanspolitik. I første scenario ses på virkningerne af en reduktion i de offentlige udgifter, mens der i det andet scenario ses på et "balanceret budget", hvor de offentlige besparelser modsvares af reduktion i de statslige indkomstskatter. Reduktion i det offentlige forbrug medfører faldende lønninger, som giver konkurrenceevneforbedringer for eksporterhvervene. Da eksporten i høj er koncentreret på de større jyske industribyer, er det især her fordelene af en kontraktiv finanspolitik kan spores, mens kommuner med mange offentligt ansatte lider tab. Hvis der samtidig sker en reduktion i indkomstskatterne, opnås fordele for kommuner med høje skattepligtige indkomster.

Under rekreative tiltag ses på skovrejsning. For at vurdere antallet af nye indbyggere som konsekvens af mere skov i en kommune, analyseredes flyttemønsteret mellem kommuner i Danmark. Befolkningen er inddelt i grupper alt efter deres status såvel primo som ultimo (arbejdsstyrke, studerende, uden for arbejdsstyrke). Endvidere er visse af grupperne opdelt efter deres uddannelsesniveau. I alt er der 11 grupper. Kun én af faktorerne i modellen er vigtig for alle grupperne – nemlig afstanden. Jo kortere afstand, des større sandsynlighed for at vælge denne flyttedestination. De øvrige faktorer har kun betydning for visse af grupperne. Kun 3 af de 11 grupper vægter andelen af skov, når de vælger flyttedestination. I tre scenarier øges andel af skov, hvilket giver anledning til en lille øgning af indflyttere. Disse nye indbyggere giver anledning til forholdsvis små stigninger i lønindkomst, overførselsindkomster og skatteindbetalinger i kommunen. Det konkluderes, at hvis man planter skov, kan man på den måde øge attraktiviteten af et område og tiltrække et mindre antal nye tilflyttere.

I *Miljøscenariet* ses på det forhold, at en fortsat udvikling af miljøreguleringen kan medføre yderligere stramninger over for landbrugsproduktionen da den gældende miljøregulering ikke opfylder målsætningerne til fulde. Der opstilles to beregningsforudsætninger, nemlig en generel og en differentieret stramning af de såkaldte harmonikrav. Harmonikravene regulerer det maksimalt tilladte antal husdyr i forhold til det areal, der er til rådighed på bedriften. Den målrettede stramning er i første scenario beregnet ved at forudsætte en større reduktion i husdyrtrykket (pr. ha) på sandjorde end på lerjorde. Den særlige stramning for bedrifter på sandjorde er begrundet i, at risikoen for udvaskning af kvælstof er større fra sandjorde end lerjorde. I andet scenario forudsættes den samme reduktion i husdyrtrykket uanset jordtype.

I begge delscenarier forudsættes en reduktion i husdyrproduktionen på 7,4% sammenlignet med basisforløbet. Hermed reduceres værdien af den samlede landbrugsproduktion. Den samlede værdi af landbrugsproduktionen reduceres med ca. 3%. De største effekter ses ikke overraskende i regioner domineret af husdyrbrug, og de største forskelle mellem den generelle og den differentierede stramning af harmonikravene er beregnet for de regioner, hvor jordtypen overvejende er sandjord. Som forventet, har den differentierede stramning størst negativ indflydelse på produktionsværdien i disse områder. Generelt påvirkes landets østlige dele relativt lidt af en stramning af harmonikravene, hvorimod betydelige effekter ses i Jylland. Disse resultater er ikke overraskende, da størstedelen af husdyrbrugene er placeret på sandjordene i de vestlige dele af landet.

I analyserne sås på virkninger for den økonomiske aktivitet, dvs. om gennemførelse/realisering af et scenario førte til koncentration eller dekoncentration.

Hvis der samtidig opstilles forskellige forudsætninger for sammenhængen mellem udviklingen i befolkning, beskæftigelse og indkomst[11], kan virkningerne af basisscenario og scenarierne med hensyn til koncentration/dekoncentration og konvergens/divergens sammenfattes således:

Tabel 2: Konsekvenser for lokal indkomst: Baseline, markedsbestemte scenarier og scenarier for politisk styring Indkomst i alt (koncentration/dekoncentration) og indkomst pr. indbygger (konvergens/divergens)

	Koncentration/dekoncentration	Konvergens/divergens
Basisscenario	Koncentration	Divergens
Markedsbestemte scenarier:		
Liberalscenario	Koncentration	Divergens
Industri	Koncentration	Divergens
Turisme	Dekoncentration	Divergens
Politisk styring:		
Velfærdsscenario	Dekoncentration	Konvergens/divergens
Rekreativ/befolkningsscenario	?	Konvergens/divergens
Miljøscenarier	Koncentration	Divergens

Det fremgår her, at de fleste scenarier ville føre til koncentration – bortset fra turisme- og velfærdsscenariet. Forklaringen på koncentration var især negative virkninger for landbruget og fremgang inden for service og avanceret industri. Dekoncentration i turismescenariet forklaredes af, at turisme gavner udkantsområderne, fordi en væsentlig del af turismen – især strandturismen – er lokaliseret her. Velfærdsscenariet førte til øget industriaktivitet som følge af reduceret offentlig service, hvilket medfører faldende lønniveau, hvilket forbedrer konkurrenceevnen for dansk eksport og dermed gavner eksportorienterede industriområder, som er mere koncentreret i Jylland.

Samtidig kunne det forventes, at basisscenariet ville føre til divergens, fordi væksten fås i erhverv med høje gennemsnitsindkomster inden for service og avanceret industri. Scenarierne ventedes[12] ligeledes at føre til divergens, fordi der fås vækst inden for erhverv med indkomster over gennemsnittet og med lokalisering i de store byer. Det bemærkedes, at turismescenariet ligeledes førte til divergens, fordi der her er tale om et lavindkomsterhverv, som opnår vækst, og som i høj grad er lokaliseret i udkantsområder, som dermed sænker gennemsnitsindkomsten i disse områder.

Fremskrivninger og scenarieanalyser er ikke alene i dansk, men også i international sammenhæng unikke både mht. geografisk detaljering og detaljering i beskrivelsen af den økonomiske aktivitet, ligesom modellens fleksibilitet mht. aggregering er meget usædvanlig.

[11] Resultaterne af analyserne af virkningerne mht. "konvergens/divergens" er ikke modelbaserede.

[12] Det bemærkes, at der ikke er udført modelberegninger, som illustrerer virkningen for indkomstfordelingen. Modelberegningerne har alene belyst konsekvenserne for koncentration og dekoncentration.

3. Faktorer, som bestemmer den regionale udvikling i Danmark[13]

For beslutningstagerne er det vigtigt at vide, hvad der bestemmer den regionale udvikling. Rationalet er – blandt de faktorer, som har betydning, og som politikerne har indflydelse på – at politikerne herved kan vælge og dosere instrumenter for at påvirke den regionale udvikling i en given retning. ***Afsnit 3*** i afhandlingen er et forsøg på at udskille faktorer, som har gjort en forskel i den regionale udvikling. I dekomponeringsanalysen anvendes LINE, som beskrives i detaljer senere i afhandlingen. Kort kan den anvendte model karakteriseres således:

$$
\begin{aligned}
y_{t_1} - y_{t_0} = {} & M^{S}_{q,ir}(Pop_{t_1}, Inctran_{t_1}, Taxrate_{t_1}, Othinc_{t_1}, Intcon_{t_1}, Pcsh_{t_1}, Pccomp_{t_1}, Tour_{t_1}, \\
& Govcons_{t_1}, Invest_{t_1}, Import_{t_1}, Export_{t_1}, ComTax_{t_1}, Prices_{t_1}, Labcont_{t_1}) \\
& - M^{S}_{q,ir}(Pop_{t_0}, Inctran_{t_0}, Taxrate_{t_0}, Othinc_{t_0}, Intcon_{t_0}, Pcsh_{t_0}, Pccomp_{t_0}, Tour_{t_0}, \\
& Govcons_{t_0}, Invest_{t_0}, Import_{t_0}, Export_{t_0}, ComTax_{t_0}, Prices_{t_0}, Labcont_{t_0}) \text{..........................(1)}
\end{aligned}
$$

hvor :

y: *primærindkomst*

$M^{S}_{q,ir}$: *LINE, som er en interregional(ir) mængdemodel(q) på strukturel form(S)*

Pop: *Befolkningens størrelse og sammensætning*

Inctran: *Indkomstoverførelses andele & beløb*

Taxrate: *Skattesatser*

Othinc: *Andre indkomster*

Intcon: *Råvareforbrug*

Pcsh: *Privat forbrugsandele*

Pccomp: *Sammensætning af det private forbrug*

Tour: *Turistforbrug*

Govcons: *Offentligt forbrug*

Invest: *Investeringer*

Import: *Import fra udlandet*

Export: *Eksport til udlandet*

ComTax: *Vareskatter og handelsmarginaler*

Prices: *Priser*

Labcont: *Arbejdskraftindhold*

t_1, t_0 : *Slutår og startår for dekomponeringen*

Det fremgår, at analysen ser på udviklingen i den primære indkomst (y). Analysen gennemføres med en model (M), som er interregional (ir), er en mængdemodel (q), som er opstillet på

[13] Jensen-Butler, Chris og Bjarne Madsen (2005): Decomposition analysis: an extended theoretical foundation and its application to the study of regional income growth in Denmark. *Environment and Planning A*.

strukturel form[14] (S). Modellen er i dette tilfælde LINE, som er en mængdemodel[15] på strukturel form, dvs. ligningerne i LINE beskriver de detaljerede sammenhæng uden matematiske løsninger af hele eller dele af modellen.

Analysen viser, at udviklingen i eksporten til udlandet, arbejdskraftindhold og det offentlige forbrug har særlig betydning for den regionale udvikling. Selvom der er tale om et generelt resultat, som ikke umiddelbart lader sig omsætte i operationelle mål og midler, understøtter analysen den generelle fokus på at forbedre den regionale konkurrenceevne, som er opnået med andre analyser (Heinesen og Groes 1997; Copenhagen Economics & Inside Consulting 2004; Inside Consulting m.fl. 2005). Vigtigt i den sammenhæng er, at der i dekomponeringsanalyse indgår en præcis geografisk reference til den forklarede variabel (y)[16], ligesom der medtages spill-over og feed-back mekanismer i den interregionale økonomi.[17]

Metodisk er analysen speciel, fordi den gennemføres med en model for den lokale økonomi, som har en hidtil uset detaljering, ligesom ex post-dekomponering med interregionale generelle ligevægtsmodeller heller ikke er set før. Metodisk har dekomponeringsanalysen sin rod i tidligere analyser af sammenhængen mellem regional udvikling og transportinfrastruktur. I Madsen (2000) redegøres teoretisk for, hvorledes virkningerne af den faste Øresundsforbindelse – for trafik såvel som regionaløkonomisk aktivitet – kan estimeres. Der opstilles en generel interregional model ("M"), hvor der teoretisk argumenteres for, at modelresultater – for en udvalgt variabel – er en funktion af nærmere specificerede eksogene og endogene variabler. Der argumenteres for, at modellen bør være en interregional generel ligevægtsmodel. Modelresultater fremkommer herefter ved at indsætte værdier af de eksogene variabler med og uden "politisk projekt" – fx transportomkostninger før og efter åbningen af den faste Øresundsforbindelse. Ændringen i regional BNP – med og uden "politisk projekt" – kan herefter opfattes som indikator for effekten af projektet. Eller trafik før og efter åbning af den faste forbindelse kan opfattes som den trafikale effekt.

Teoretisk rendyrkes metoden i transportanalyser (Madsen og Jensen-Butler 2001), idet forskellige typer effektberegninger klassificeres efter tidshorisont (ex ante- og ex post-beregninger) og tekniske krav til dekomponeringsteknikken – fx sumrestriktioner for effekten af de enkelte dekomponeringsbidrag.

I Madsen m.fl. (1998) Ekspertudvalget (1998) og Jensen-Butler m.fl. (2002) anvendes teknikken med en forenklet version af LINE til at dekomponere udviklingen i primærindkomst henholdsvis disponibel indkomst pr. indbygger. Der er her tale om ex post-analyser[18].

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[14] En model på strukturform beskriver alle detaljerede flow i økonomien. Dette står i modsætning til modeller på reduceret form, hvor hele modellen eller dele af den er løst, hvorefter modellen er anvendt i modelanalysen. Faren ved brug af modeller på reduceret form er risikoen for negligering af skift i underliggende variabler.

[15] LINE indeholder også en prismodel. I den givne version var priserne eksogent givne.

[16] I analysen ses på betydningen af at dekomponere en indkomstvariabel, som henregnes til produktionssted eller bopæl, og det konkluderes, at det har stor betydning for analyseresultatet, om variablen er en produktionssteds- eller bopælsvariabel. Dette har vist sig bl.a. at være et centralt kritikpunkt af den regionale konkurrenceevnemodel.

[17] Analysen er interregional, hvilket vil sige, at den økonomiske aktivitet i en region ikke alene afhænger af den økonomiske aktivitet i regionen selv, men også af aktiviteten i andre regioner. Dette har vist sig bl.a. at være et centralt kritikpunkt af den regionale konkurrenceevnemodel (Christoffersen og.Windelin 2007).

[18] Det bemærkes, at de fleste analyser med LINE er ex ante-analyser, hvor effekterne af et givet projekt i en nærmere specificeret fremtid vurderes.

I Madsen og Jensen-Butler (2002) og i Jensen-Butler og Madsen (2005) anvendes dekomponeringsteknikken med en fuld version af LINE (den interregionale mængdemodel) til at dekomponere udviklingen i primærindkomst henholdsvis disponibel indkomst pr. indbygger for danske kommuner.

Metodemæssigt adskiller dekomponeringsanalysen sig fra de metoder, som har været anvendt i den danske debat. Her anvendes modeller på reduceret form – dvs. en- eller to-lignings-modeller – fx

$$y_{t_1} - y_{t_0} = M^{R}_{q\,i\,r}(Exovar_{1,t_1}, Exovar_{2,t_1}, Exovar_{3,t_1}, ..., Exovar_{n,t_1},$$
$$dExovar_{1,t_1-t_0}, dExovar_{2,t_1-t_0}, dExovar_{3,t_1-t_0}, ..., dExovar_{m,t_1-t_0}) ....(2)$$

hvor :

y: *indkomst eller gennemsnitsindkomst*

$M^{R}_{q,ir}$: *LINE, som er en interregional(ir) mængdemodel(q) på reduceret form(R)*

Exovar : *Variabel, sombetragtes som eksogen for den regionaleudvikling*

dExovar : *Ændring i en variabel, som betragtes som eksogen for den regionale udvikling*

t_1, t_0 : *Slutår og startår for vækstanalysen*

Her ses på en enkeltligningsforklaring af den regionale udvikling. Det fremgår, at ligningen enten kan se på koncentration/dekoncentration (indkomst) eller konvergens/divergens (gennemsnitsindkomst). Det forudsættes her, at modellens eksogene variabler – hvad enten de er i niveau eller i differens – er afledt (dvs. matematisk løst) af en teoretisk model på strukturel form. Eksempler på denne type én-ligningsanalyser er Dilling-Hansen og Smith (1997) og Heinesen og Groes (1997). I tilfældet, hvor den regionale økonomi beskrives med 2 ligninger – dvs. matematisk reduceret fra en model på strukturel form til 2 ligninger – ændres udtrykket. Eksempel på 2-ligningsforklaring af den danske regionaløkonomis udvikling er Kristensen og Henry (1997).

Når der anvendes modeller på reduceret form, benyttes økonometrisk estimation af ligningen (rne). Når der er tale om en model på strukturel form, vil modellens ligninger typisk være kalibrerede, hvilket fx er tilfældet for LINE[19].

I en international sammenhæng adskiller ex post-dekomponeringen sig ved anvendelse af en udbygget interregional generel mængdemodel. Endvidere argumenteres for, at beregnings-rækkefølgen i dekomponeringen bør afspejle den kausale struktur i den anvendte model – og ikke blot permuteres for at finde variationen i beregningsresultatet for forskellige mulige beregningsrækkefølger.

[19] For enkelte ligninger kan anvendes økonometrisk estimerede ligninger, fx hentet fra studier af den nationaløkonomiske udvikling.

B. Den generelle interregionale model og LINE

Afhandlingens vigtigste forskningsmæssige bidrag vedrører opstilling og løsning af den generelle interregionale model og anvendelse af denne model til analyser af regional og lokal udvikling samt forandringer i grundlag for den regionale og lokale økonomi.

Arbejdet med at formulere en generel interregional lokaløkonomisk model har pågået i en halv snes år og er løbende blevet dokumenteret i arbejdsrapporter og tidsskriftsartikler. Modellen består af en mængdemodel, som beskriver den interregionale økonomiske aktivitet målt i mængder og som præsenteres teoretisk i ***afsnit 4***, og en prismodel, som beskriver dannelsen af priser og indkomster, og som præsenteres teoretisk i ***afsnit 5***. I ***afsnit 6*** sammenstilles mængde- og prismodellen og den formuleres i differens for – teoretisk – at kunne illustrere de regionale og lokale virkninger af demografiske ændringer af befolkningsændringer. I ***afsnit 7*** eller Madsen og Jensen-Butler (2002a og 2003) præsenteres den lokaløkonomiske model LINE, som en empirisk model, der består af en interregional mængde- og prismodel, og der præsenteres 10 forskellige anvendelser af LINE. I ***afsnit 8*** præsenteres en holistisk empirisk model, hvor LINE er indbygget i et samlet modelsystem bestående af en model for den internationale økonomi (GTAP), for den nationale økonomi (AAGE), for den lokale landbrugssektor (ESMERALDA), for transportaktiviteter (MERGE) samt LINE.

4. En teoretisk model for produktion, indkomst og beskæftigelse i en interregional økonomi[20]

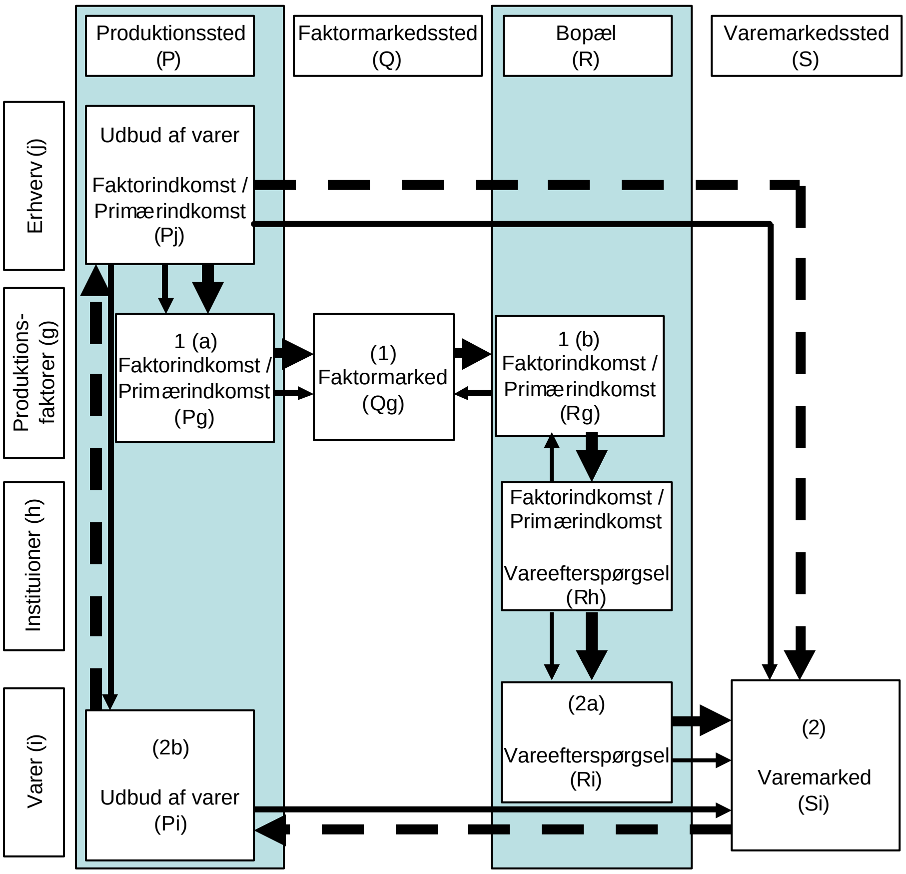
I Madsen (2007a og 2007b) generaliseres principperne bag LINE i formuleringen af den teoretiske, generelle interregionale mængdemodel henholdsvis prismodel. I dette afsnit gives et overblik over den generelle interregionale mængdemodel, som præsenteres i ***afsnit 4*** og de forskningsarbejder, som leder frem til formuleringen af denne model. Som det ses, er den regionale og ikke mindst den lokale udvikling bestemt af et komplekst system af faktorer, som dels er bestemt af områdets geografiske funktion dels af dets socioøkonomiske funktion. Hermed menes, at udviklingen i et geografisk område også er bestemt af den økonomiske udvikling i andre geografiske områder, ligesom udviklingen i et erhverv er afhængig af udviklingen i andre erhverv, af udviklingen i befolkning, arbejdsmarked, efterspørgsel mv. Den generelle model for den lokale økonomi, som præsenteres i denne afhandling, præsenterer for første gang gennem det såkaldte 2 x 2 x 2-princip på systematisk måde det økonomiske samspil internt og eksternt for den lokale økonomi og afspejler derigennem forskellige funktioner i den lokale økonomi og samspillet mellem økonomien i regionen selv, i andre regioner og udlandet.

4.1. Basal struktur af den generelle interregionale mængdemodel

Kernen i afhandlingen er den lokale økonomi. Modsat den regionale økonomi omfatter den lokale økonomi flere detaljer (se figur 1):

[20] Madsen, Bjarne (2007): The General Interregional Quantity Model.

Figur 1. Den begrebsmæssige basis for den generelle interregionale mængdemodel



Hvor den regionale økonomi i geografisk henseende er afgrænset som pendlingsopland og/eller handelsopland, inkluderer den lokale økonomi yderligere interaktion på faktormarkedet og varemarkedet.

På *faktormarkedet* (felt Qg i figur 1) indgår pendling mellem produktionssted (Pg) og bopæl (Rg). Pendling omfatter alle produktionsfaktorer: arbejdskraft, kapital og jord samt underinddelinger af disse produktionsfaktorer. Produktionsenhederne, som geografisk er placeret på produktionsstedet (Pj), genererer efterspørgsel efter produktionsfaktorer, dvs. efterspørgsel efter arbejdskraft (arbejdspladser), kapital og jord (Pg). Institutioner, som geografisk henhører på bopælen (Rh), udbyder produktionsfaktorer (Rg). Husholdningerne udbyder arbejdskraft. Husholdninger/personer, selskaber og firmaer udbyder finansiel kapital, som finansierer den reale kapital på produktionsstedet. Jorden stilles til rådighed for jordforpagterne[21] af jordejerne, hvor jordejerne kan være husholdninger/personer, selskaber og firmaer. Den offentlige sektor opfattes her som institutioner, som kan eje jord og kapital.

Udbuddet og efterspørgslen af produktionsfaktorer mødes geografisk på faktormarkedsstedet (Qg), hvor arbejdskraft, kapital og jord formidles. Den geografiske formidling af produktionsfaktorer er pendling. I analyser af den regionale økonomi antages produktionssted og bopæl at være det samme, hvorved pendling inden for regionen reduceres væk. Regionale modeller kan

[21] Jordforpagteren kan være jordejeren selv.

på den måde karakteriseres som modeller på reduceret form, mens lokale modeller er modeller på strukturel form, hvor de geografiske detaljer modelleres eksplicit.

I regionalanalyser er modellen også reduceret, når man ser på beskrivelsen af den økonomiske aktivitet: I regionalanalyser ses normalt alene på økonomisk aktivitet opdelt efter erhverv (J), mens der i analyser af den lokale økonomi herudover indgår en opdeling af økonomiske aktiviteter efter institutioner (H), produktionsfaktorer (G) og varer (I). Institutioner er opdelt efter type, fx husholdninger efter ægteskabelig status og børn/ikke børn (Rh). Ligeledes ses i lokale analyser også på typen af produktionsfaktorer (Pg og Rg) og markeder for produktionsfaktorer (Qg): For arbejdskraft kan eksempelvis opdeles i køn, alder og uddannelse, mens markedet for jord kan opdeles efter anvendelse – fx boligformål, erhvervs- eller produktionsformål mv. Finansiel kapital kan også opdeles efter forskellige typer. Denne "Social Accounting"-opdeling af produktionsfaktorer kan igen opfattes som en beskrivelse af den lokale økonomi på strukturel form modsat den regionale analyse, som implicerer en reduktion af centrale karakteristika, såsom type af faktormarkeder og type af institution. Regionalanalyser kan tolkes som analyser, som alene ser på én type produktionsfaktor eller én type institution.

På *varemarkedet* er der i den regionale analysemodel ligeledes tale om reduktioner (se figur 1). I den lokale økonomi ses på udbud og efterspørgsel af varer som en proces i to trin, som i regionalanalysen er reduceret til et trin. I den lokale økonomi foregår produktionen på produktionsstedet (Pj), mens efterspørgslen i væsentlig grad skabes på bopælen (Rh)[22]. Udbud og efterspørgsel mødes på varemarkedsstedet (Si). Den geografiske interaktion deles derfor i den lokaløkonomiske analyse i to trin: Handel med varer og tjenester, som er interaktionen mellem produktionsstedet (Pi) og varemarkedsstedet (Si), og indkøb af varer, som er interaktionen mellem bopæl (Rh) og varemarkedsstedet (Si). I regionalanalysen reduceres til en direkte relation mellem produktionssted (Pj) og bopæl (Pj) uden udskilning af indkøbsdelen fra handelsdelen.

I regionalanalyser af varemarkedet er analyserne også reducerede, når man ser på beskrivelsen af økonomiske aktiviteter. I den regionale analyse ses alene på økonomiske aktiviteter opdelt på erhverv, mens der i den lokaløkonomiske analyse opdeles i 2 trin: Fra erhverv til varer (varehandel fra Pj til Pi) og fra varer til institutioner (shopping med privat forbrug mv. – fra Si til Rh) henholdsvis fra varer til sektorer (råvareforbrug – fra Si til Pj). Denne "Social Accounting" opdeling af det lokale marked repræsenterer en beskrivelse af aktiviteterne på strukturel form, mens regionalanalysen er på reduceret form.

I Madsen m.fl. (1999) udvikledes for første gang de centrale begreber, produktionssted (P), bopæl (R), faktormarkedssted (Q) og varemarkedssted (S)[23] I beskrivelsen af den interregionale Social Accounting Matrix blev der lagt vægt på udskilning af et specifikt varemarked, som herefter var udgangspunkt for todeling i en efterspørgselsside, som involverer indkøbsrejser fra bopæl (Ri)/produktionssted (Pi) til varemarkedssted (Si), og en udbudsside, som involverer handelsrejser fra produktionssted (Pi) til varemarkedssted (Si).

I Madsen og Jensen-Butler (1999b) argumenteres for, at den institutionelle input-output-tabel (eller sektor gange sektormodellen eller j x j-modellen) bør opdeles i use-matricer, som for

[22] Efterspørgslen efter råvarer udgår dog fra produktionsstedet.

[23] I Madsen m.fl. (1999) benyttes begrebet "efterspørgselssted" i stedet for "varemarkedssted". "Varemarkedssted" er senere indført for at understrege, at begrebet involverer både en efterspørgsels- og udbudsside.

forskellige typer efterspørgsel fordeler efterspørgslen fra erhverv/komponenter til varer[24] (Pj til Si henholdsvis Rh til Si) og i en make-matrix (Pj til Pi), som repræsenterer transformation fra det producerende erhverv til den producerede vare.

Med en lokaløkonomisk model åbnes således mulighed for at opnå en dækkende måling af multiplikatorvirkningen af ændringer i den lokale økonomi. I den lokale økonomi forsvinder en økonomisk påvirkning ud af den lokale økonomi, når der pendles ind, når der købes ind i andre lokalområder eller lokalområdets befolkning er turister i andre lokalområder, ligesom virkningerne også forsvinder fra den lokale økonomi i det omfang, efterspørgslen dækkes af produktion fra andre lokalområder. I den forstand er modellen for den lokale økonomi mere dækkende for lækager i den lokale økonomi, hvor den konventionelle regionale model alene tager hensyn til handels-lækager.

4.2. 2 x 2 x 2-princippet

Overvejelserne, som er et hovedbidrag til afhandlingen og som repræsenterer et nyt grundlag for formulering af interregionale økonomiske modeller, generaliseres i det såkaldte 2 x 2 x 2-princip. Princippet er illustreret i figur 1 i afsnit 4.1.

For *det første* indgår i den lokale økonomi – som den klassiske økonomi – to agenter, dvs. producenter (Pj) og institutioner (Rh). Institutioner kan være grupper af mennesker, som er forbundet i forskellige relationer, fx husholdninger, kommuner/nationer, firmaer, selskaber, foreninger mv. I social accounting-terminologi inddeles i institutions- eller husholdningstyper (h). Producenter er igen grupper af mennesker, som indgår i en fælles produktionsaktivitet. Produktionsaktiviteter inddeles i erhverv (j). Til institutionerne knyttes det geografiske begreb bopæl (R). Til produktionen knyttes det geografiske begreb produktionssted (P).

For *det andet* indgår i den lokale økonomi – som den klassiske økonomi – to markeder, varemarkedet (Si) og faktormarkedet (Qg). Varemarkedet omfatter produkter og serviceydelser. Inden for social accounting-traditionen inddeles efter varegrupper (i). Faktormarkedet omfatter produktionsfaktorer (g) som arbejdskraft, kapital og jord. Tilsvarende inddeles produktionsfaktorer i forskellige typer, fx arbejdskraft efter køn, alder og uddannelse.

Til varemarkedet knyttes det geografiske begreb varemarkedssted (S), mens der til faktormarkedet knyttes begrebet faktormarkedsstedet (Q). Varemarkedsstedet er den geografiske placering af detailhandelen for så vidt angår forbrugsgoder, mens det for erhvervenes råvareforbrug og for investeringer er engroshandlens geografiske lokalisering.[25]

For faktormarkedet er faktormarkedsstedet den geografiske placering af formidling af produktionsfaktorer. Ser man på produktionsfaktoren arbejdskraft, kan begrebsdannelsen illustreres således: På faktormarkedsstedet indgås juridiske aftaler om køb og salg af arbejdskraft. Som for varehandlen eksisterer en detailhandels- og engroshandelsfunktion for køb og salg af arbejdskraft. Ved detailhandelsfunktionen er der tale om formidling af arbejdskraft til endelig anvendelse (fx i husholdninger), dvs. i forbindelse med forbruget af arbejdskraften foregår der

[24] For use-matricen for råvareefterspørgsel er der tale om en transformation fra råvareforbrug opdelt på erhverv til råvareforbrug opdelt på varer. For use-matricen for det private forbrug er der tale om en fordeling af det private forbrug på forbrugskomponenter til det private forbrug på varer.

[25] I denne forbindelse bemærkes, at der for både detailhandel og engroshandel eksisterer det såkaldte biprodukt-fænomen, hvor detailhandel også sælger varer til erhvervene og til investeringsprojekter, dvs. udfører en engroshandelsfunktion ligesom engroshandel også i en vis udstrækning udfører detailhandelsfunktion over for institutioner.

ikke videresalg af aktiviteten. Ved engroshandelsfunktionen på faktormarkedet foregår der i forbindelse med formidlingen af arbejdskraften et salg af arbejdskraft til produktionsfirmaer.

For *det tredje* eksisterer en geografisk sammenbinding af udbud og efterspørgslen på de to markeder. For faktormarkedet er der tale om pendling (fra Pg til Qg og videre til Rg). Pendlingen går fra institutionens bopæl til produktionsstedet via faktormarkedet. Hvis der i geografisk forstand eksisterer et egentligt faktormarkedssted, kan pendlingen deles i to transporter: Fra institutionens bopæl til faktormarkedsstedet og fra faktormarkedsstedet til produktionsstedet. I tilfældet kapital kan man se faktormarkedsstedet som det sted, hvor der stilles finansiel kapital til rådighed, fx udlån (bankers aktiviteter) eller det sted, hvor selskaber stiller finansiering til rådighed for fysiske produktionsenheder, som herefter kan indkøbe fysisk kapital over varemarkedet.

For varemarkedet er der en mere velkendt inddeling af den geografiske transformation fra produktionsstedet til varemarkedsstedet (fra Pi til Si) og fra varemarkedsstedet til institutionens bopæl (fra Si til Ri) henholdsvis til produktionsenhedens produktionssted (fra Si til Rj). Den geografiske transformation fra produktionssted til varemarkedssted betegnes normal varehandel, som evt. kan underdeles i intraregional, interregional og international varehandel. Den geografiske transformation fra varemarkedssted til institutionens bopæl henholdsvis produktionens produktionssted betegnes normalt shopping eller indkøbsrejser. Der eksisterer forskellige typer shopping: Det lokale, private forbrug dækker det, man normalt vil forbinde med shopping. Imidlertid er turisme en særlig form for shopping, hvor turisterne bevæger sig fra institutionernes bopæl (privat turisme)/produktionens produktionssted (erhvervsturismen) til turiststedet, hvor turistregionen er varemarkedsstedet for turisten (Madsen m.fl. 2003; Zhang m.fl. 2007). For offentligt forbrug er der tale om shopping, hvor der eksisterer en bopæl for det offentlige forbrug (typisk bopælen for borgeren, som "modtager" det offentlige forbrug) og varemarkedsstedet, hvor det offentlige forbrug indkøbes (typisk produktionsstedet for den offentligt producerede vare). For en nærmere diskussion se Madsen (2003). For erhvervenes råvareforbrug og for investeringer er der ligeledes tale om shopping. Ofte foregår shopping ved indkøb i engroshandlen.

4.3. Implementering af 2 x 2 x 2-princippet i den interregionale mængdemodel for den lokale økonomi

Den teoretiske begrebsmodel kan anvendes i formulering af en interregional makroøkonomisk model for den lokale økonomi. Den generelle interregionale mængdemodel formuleres i afhandlingens afsnit 4 dels grafisk, dels matematisk.

Grafisk kan modellen vises i figur 1 i afsnit 4.1. Som det fremgår af figuren (de fedt stiplede linjer) er den grafiske model en sekventiel model, som går med uret og regner fra produktion til indkomst (fra Pj til Rh i figur 1), fra indkomst til forbrug (fra Rh til Si og fra Pj til Si) og fra forbrug til produktion (fra Si til Pj). Strukturen i den matematiske model på strukturel form er som følger:

$$y = M^{S}_{q,ir}(g^{P}_{j}, Q^{P}_{j,g}, J^{P,Q}_{g}, J^{Q,R}_{g}, pv^{R,D}_{g}, H^{R}_{g,h}, pu^{R}_{CP,h}, b^{R}_{CP,i}, B^{R}_{CP}, S^{R,S}_{CP,i}, b^{P}_{IC,i}, B^{P}_{IC}, S^{P,S}_{IC,i}, d^{S,F}_{i}, T^{S,P}_{i}, D^{P}_{i,j},$$

$$z^{P,F}_{i}, u^{S,F}_{IC,i}, u^{S,F}_{CP,i}, u^{S}_{CO,i}, i^{S}_{I,i}) \ldots\ldots (3)$$

hvor :

g^{P}_{j} : *Arbejdskraftindhold af produktionsværdi*

$Q^{P}_{j,g}$: *Beskæftigelsens sammensætning mht. arbejdskraft*

$J^{P,Q}_{g}, J^{Q,R}_{g}$: *Pendlingskoefficienter mellem produktionssted og bopæl*

$pv^{R,D}_{g}$: *Omkostningsindeks for arbejdskraft*

$H^{R}_{g,h}$: *Husholdningstyper for typer af arbejdskraft*

$pu^{R}_{CP,h}$: *Prisindeks for privat forbrug*

$b^{R}_{CP,i}$: Pr*ivate forbrugsandele*

B^{R}_{CP} : *Varesammensætning af det private forbrug*

$S^{R,S}_{CP,i}$: *Shopping for privat forbrug*

$b^{P}_{IC,i}$: *Råvareforbrug andel*

B^{P}_{IC} : *Råvareforbrugets varesammensætning*

$S^{P,S}_{IC,i}$: *Shopping for råvareforbrug*

$d^{S,F}_{i}$: *Importandel for import fra udlandet*

$T^{S,P}_{i}$: *Intra – og interregional handel*

$D^{P}_{i,j}$: *Produktionens varesammensætning*

j : *Erhverv*

g : *Produktionsfaktorer*

h : *Institutioner / husholdninger*

i : *Varer*

P : *Produktionssted*

Q : *Faktormarkedssted*

R : *Bopæl*

S : *Varemarkedssted*

Det fremgår, at modellen M er en model på strukturel form (S), som er interregional (ir). Produktionen (y) afhænger af den eksogene efterspørgsel (variabler i ligningens 2. linje) og af en række transformationsmatricer (variabler i ligningens første linje).

Når modellen på strukturel form løses, fås følgende udtryk på reduceret form:

$$y = M^{R}_{qir}$$

$$= Multiplikator(g^{P}_{j}, Q^{P}_{j,g}, J^{P,Q}_{g}, J^{Q,R}_{g}, pv^{R,D}_{g}, H^{R}_{g,h}, pu^{R}_{CP,h}, b^{R}_{CP,i}, B^{R}_{CP}, S^{R,S}_{CP,i}, b^{P}_{IC,i}, B^{P}_{IC}, S^{P,S}_{IC,i}, d^{S,F}_{i}, T^{S,P}_{i}, D^{P}_{i,j})$$

$$\bullet\ Eksogene\ variabler(z^{P,F}_{i}, u^{S,F}_{IC,i}, u^{S,F}_{CP,i}, u^{S}_{CO,i}, i^{S}_{I,i}) \ldots\ldots (4)$$

Det fremgår her, at modellens løsning består af en multiplikator og en række eksogene variabler.

Mængdemodellen kan betegnes som en keynesiansk efterspørgselsmodel med a) interregionale leverancer fra produktion til bopæl, fra bopæl til varemarkedssted og fra varemarkedssted til produktionssted og med b) leverancer mellem forskellige SAM-grupper, svarende til 2 x 2 x 2-princippet.

Den generelle interregionale mængdemodel adskiller sig på forskellige måder fra den eksisterende tradition for interregionale input-outputmodeller, fx formuleret af Isard (1951) eller Chenery-Moses (Chenery 1953; Moses 1955): For det første opdeles relationen mellem erhverv og erhverv i relationer mellem erhverv og varer (use-matricer) og mellem varer og erhverv (make-matricer) (Madsen og Jensen-Butler 1999b). Der argumenteres for, at den opdelte model beskriver adfærden for producenter mere adækvat, idet både sammensætningen af råvarer (use-matricen) og sammensætningen af produkter (make-matricen) modelleres eksplicit. Geografisk opdeles råvareefterspørgslen i overgangen fra produktionssted til varemarkedssted (use-matricen), som etablerer shopping med råvarer, og fra varemarkedssted til produktionssted (make-matricen), som beskriver handel med færdigvarer. På denne måde adskiller den generelle interregional model sig fra Isard- henholdsvis Chenery-Moses-modellerne. I Isard-modellen sammenkobles endelig anvendelse i en region med produktion i en anden region, mens der i Chenery-Moses modellen anvendes en pool tilgang.

For det andet formuleres relationen mellem produktion og indkomst i en mængderelation mellem produktion og beskæftigelse og en relation mellem beskæftigelse og indkomst. Relationen underinddeles i en relation mellem

- produktion og arbejdspladser, som bestemmer antal arbejdspladser,
- arbejdspladser og beskæftigelse, som bestemmer pendlingen og beskæftigelsen efter bopæl,
- beskæftigelse, indkomstsats, som bestemmer indkomsten i værdi.

Hermed sondres mellem produktionssted (P), faktormarkedssted (Q) og bopæl (R) og mellem aktiviteter opdelt efter erhverv (j), faktorgrupper (g) og efter husholdningstyper (h).

I interregionale input-outputmodeller, hvori indgår inducerede virkninger – fx Miyazawa (1976) – kobles direkte mellem produktionsværdi og indkomst, hvilket kan betragtes som en reduktion af den underliggende relation mellem produktion, beskæftigelse og indkomst. I de klassiske Isard- og Chenery-Moses-modeller er forbruget fastsat eksogent, og der er ingen opdeling på indkomst efter faktorgruppe eller husholdningstype, hvorimod Miyazawa har en opdeling på husholdningstyper.

For det tredje opdeles relationen mellem efterspørgsel og produktion i en relation mellem efterspørgsel efter bopæl og efterspørgsel efter varemarkedssted og i en relation mellem varemarkedssted og produktionssted. I Isard- og Chenery-Moses-modellerne reduceres disse to relationer til én relation. Opdelingen indebærer både en transformation fra husholdninger til varer og en transformation fra varer til erhverv. Geografisk fører dette til en opsplitning af vareflowet fra bopæl til varemarkedssted (shopping/turisme) og fra varemarkedssted til produktionssted (varehandel).

Mængdemodellen opskrives i ***afsnit 4*** matematisk under anvendelse af 2 x 2 x 2-princippet. Den matematiske formulering af den generelle interregionale mængdemodel bygger videre på

Greenstreet (1987), som inkluderer make-, handel- og use-matricer i formuleringen af den interregionale mængdemodel. Den generelle interregionale mængdemodel løses analytisk, og repræsenterer dermed en kvalificering af den "Leontief-inverse" til også at inkludere geografiske transformationer som handel, pendling, shopping og turisme og SAM-transformationer fra erhverv til faktorgrupper, fra faktorgrupper til institutioner, fra institutioner til varer og fra varer tilbage til erhverv.

4.4. 2 x 2 x 2-princippet og en typologi for regionale og lokale økonomier

Klassificeringer af regioner tager normalt udgangspunkt i specialisering og produktivitet, hvilket som regel afspejler en forankring i handelsteori, hvor et lokalområde specialiserer sig inden for funktioner, hvor området har komparative fordele. Normalt anvendes lokaliseringskoefficienter til beskrivelse af specialisering. I ***afsnit 4*** anvendes den generelle interregionale mængdemodel som udgangspunkt for en klassificering af lokaløkonomier i overensstemmelse med deres lokaløkonomiske funktion. I den klassificering forbindes lokalområder både efter specialisering og interaktion: For det første karakteriseres visse lokalområder efter deres funktion som (netto-)eksportører af varer, hvor der fx kan sondres mellem primær, sekundær og tertiær produktion. For det andet adskiller visse lokalområder sig ved deres funktion som bopælsområder, hvor (netto-)udpendlingen er betydelig. Igen her kan bopælsområder underinddeles efter forekomsten af særlige befolkningsgrupper (fx ældrekommuner eller kommuner for erhvervsaktive). For det tredje udskiller nogle kommuner ved deres funktion som varemarkedssted, fx detailhandels- eller engroshandelscentre eller ved salg – og produktion – service, fx kulturelle aktiviteter eller specialiseret offentlig service (fx sygehusproduktion).

Det centrale i overvejelser vedr. klassificering eller typologisering af lokalområder er altså ikke alene lokalområdet isoleret betragtet, men som afhængig af lokalområdets placering i den lokale økonomi. Betragtet som en afhængig lokaløkonomi er de afledte virkninger eller multiplikatorvirkningen mindre jo større lækager ud af området, hvad enten der er tale om handel, shopping, turisme eller pendling.

Typologien har fundet anvendelse i Zhang m.fl. (2007), som benytter LINE til at gennemføre multiplikatorberegninger, som viser konsekvenserne af ændret turisme i forskellige regioner i Danmark – dvs. hovedstadsområdet som metropol, de større byer, landområder med tilknytning til de større byer og landområder med svag tilknytning til byerne. I artiklen forklares multiplikatorvirkninger af øget turisme af omfanget af lækager i det enkelte område, dvs. handlen med andre regioner og udlandet, pendling ind og ud af området, shopping ind og ud af området samt turisme ind og ud af området.

5. En teoretisk model for omkostninger, priser og indkomst i en interregional økonomi[26]

Inden for input-output-modeller udgør prismodellen den duale til mængdemodellen. I input-output-prismodellen bestemmes prisen ud fra et simpelt adding-on princip. Hvor mængdemodellen kan ses som en model, der inkluderer såkaldte "backward linkages", dvs. mængdevirkninger for underleverandør (de indirekte virkninger) og afledt forbrug (de inducerede virkninger), omfatter prismodellen såkaldte "forward linkages". I prismodellen beregnes, hvorledes en omkostningsændring – fx forøgede lønomkostninger – overvæltes på virksom-

[26] Madsen, Bjarne (2007): The General Interregional Price Model.

hedernes priser, som igen væltes videre på priser på varer solgt til næste led i produktionskæden osv.

I den sammenhæng er det relevant, at modellere disse overvæltningsmekanismer i en lokal økonomi. Hvorledes påvirker omkostningsændringer prisen på produkter produceret i et givet område? Og hvorledes påvirkes omkostninger og priser af transportomkostninger for varer, som transporteres fra et produktionssted til et varemarked og videre til den næste producent i produktionskæden? Osv. Og hvorledes påvirkes prisen på varer, som leveres til endelig anvendelse – fx privat forbrug eller eksport til udlandet – af omkostninger ved produktion af varen og ved transport af varen frem til slutbrugeren?

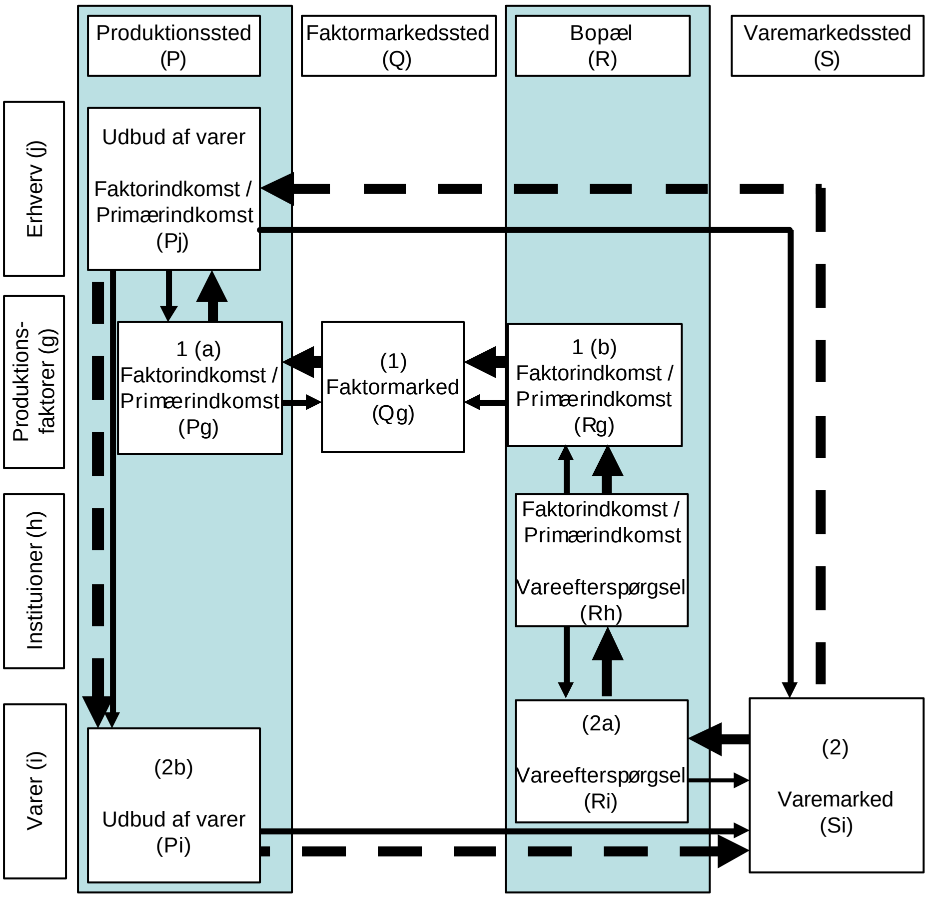
Arbejdet med at formulere en generel interregional prismodel er sket som led i modellering af regionale konsekvenser af infrastrukturinvesteringer og regulering af transportsektoren – jf. ***hovedafsnit D***. Ændringer i transportomkostninger påvirker priser på varer (produkter og service). Modelleringen af transportomkostningseffekter var i de første arbejder alene modellering af "ydre påvirkninger". Her påvirker transportomkostningen eksportprisen (konkurrenceevne), som igen påvirker eksportmængden, som igen påvirker vareefterspørgslen til den interregionale mængdemodel (Jensen-Butler og Madsen 1996; 2004). Senere blev modellering af omkostninger og priser fuldt integreret i den generelle interregionale prismodel, som sammen med den generelle interregionale mængdemodel indgår i en samlet generel interregional model (Madsen m.fl. 2002a; Madsen og Jensen-Butler 2004b; Madsen 2007b).

Den generelle interregionale prismodel, som præsenteres i ***afsnit 5***, giver for første gang en detaljeret beskrivelse af dannelsen af omkostninger og priser i den lokale økonomi, modsat den generelle nationale prismodel (Miller og Blair 1985), den interregionale version af input-output-prismodellen (Toyomane 1986) eller interregionale generelle ligevægtsmodeller (Bröcker 1998). Basalt benyttes samme begreber og modelstruktur som i den generelle interregionale mængdemodel, dvs. 2 x 2 x 2-princippet, idet mængdemodellens koefficienter indgår som vægte i omkostnings- og prisberegningen. Den interregionale prismodel er meget nyttig, fordi den beskriver, hvorledes omkostnings- og prisændringer slår igennem i forskellige lokalområder og er dermed et vigtigt element i bestemmelsen af regionale og lokale multiplikatorer.

5.1. Basal struktur af den generelle interregionale prismodel

Dannelsen af omkostninger og priser i den lokale økonomi kan illustreres i følgende figur (se figur 2):

Figur 2. Den begrebsmæssige basis for den generelle interregionale prismodel



Grafisk følger prismodellen mængdemodellen (jf. figur 1 i afsnit 4 og figur 2 i dette afsnit), blot med den forskel, at den bevæger sig den modsatte vej, dvs. mod uret (jf. de stiplede pile). Den generelle interregionale prismodel er – som mængdemodellen – en sekventiel model. Prismodellen følger et simpelt mark up-princip, som betyder, at omkostningsændringer overvæltes krone for krone på priserne i næste led i produktionskæden.

Den generelle interregionale prismodel adskiller sig på forskellig måde fra den eksisterende tradition for interregionale input-output-modeller: Som det er tilfældet for interregionale mængdemodeller, er traditionen at benytte den institutionelle tilgang, hvor leverancer mellem erhvervene beskrives i reduceret form. I den generelle interregionale prismodel opdeles relationen mellem erhverv til relationer mellem erhverv og varer (use-matricer) og mellem varer og erhverv (make-matricer) (Madsen og Jensen-Butler 1999b). I den generelle interregionale prismodel bliver omkostnings- og priseffekter transformeret fra erhverv til varer og fra varer tilbage til erhverv. Geografisk opdeles prisdannelsesprocessen i overgangen fra produktionssted til varemarkedssted, som beskriver overgangen fra produktionssted (Pi) til varemarkedssted (Si) (interregional handel), og overgangen fra varemarkedssted til produktionssted (shopping med råvarer), som etablerer shopping med råvarer fra varemarkedssted (Si) til produktionssted (Pi). På den måde adskiller den generelle interregionale prismodel sig fra Isard- henholdsvis Chenery-Moses-modellerne (se Toyomane 1986). I Toyomane sammenkobles prisen på endelig anvendelse i en region med prisen på produktion i en anden region.

For det andet formuleres dannelsen af indkomster på grundlag af den interregionale mængdemodels relation mellem produktion og beskæftigelse og mellem beskæftigelse og indkomst. Dannelsen af indkomster underinddeles i en relation mellem

- beskæftigelse, indkomstsats og indkomst,
- arbejdspladser og beskæftigelse (pendling), og
- produktion og arbejdspladser.

Hermed sondres mellem bopæl (R), faktormarkedssted (Q) og produktionssted (P) og mellem aktiviteter opdelt efter husholdningstyper (h), faktorgrupper (g) og efter erhverv (j). I interregionale input-output-modeller indgår ikke inducerede pris- og indkomstvirkninger – se fx Toyomane (1986), hvor der alene opereres med indirekte effekter.

5.2. Implementering af 2 x 2 x 2-princippet i den interregionale prismodel for den lokale økonomi.

Prismodellen opskrives i ***afsnit 5*** (Madsen 2007b) matematisk under anvendelse af 2 x 2 x 2-princippet:

$$px = M^{S}_{pir}(D^{P}_{i,j}, T^{S,P}_{i}, d^{S,F}_{i}, S^{P,S}_{IC,i}, B^{P}_{IC}, b^{P}_{IC,i}, S^{R,S}_{CP,i}, B^{R}_{CP}, b^{R}_{CP,i}, H^{R}_{g,h}, J^{Q,R}_{g}, J^{P,Q}_{g}, Q^{P}_{j,g}, g^{P}_{j},$$
$$pz^{S,F}_{i}, pu^{P,F}_{IC,i}, pu^{R,F}_{CP,i}, pvx^{R}_{h}, pvx^{R}_{g}, pv^{P,F}_{g}, pvx^{P}_{j}) \text{.................................} (5)$$

hvor

px: *Prisen på lokal produktion*

$pz^{S,F}_{i}$: *Prisen på import fra udlandet*

$pu^{P,F}_{IC,i}$: *Prisen på råvarer indkøbt i udlandet*

$pu^{R,F}_{CP,i}$: *Prisen på privat forbrug i udlandet*

pvx^{R}_{h} : *Prisen på den del af indkomsten, som ikke forbruges*

pvx^{R}_{g} : *Prisen på den del af indkomsten, som indtjenes i udlandet*

$pv^{P,F}_{g}$: *Prisen på den del af indkomsten, som indtjenes af udlændinge i hjemlig produktion*

pvx^{P}_{j} : *Prisen på indkomst i produktionen, som fastsættes uafhængigt af priser på privat forbrug*

Som det fremgår, bestemmes prisen på lokal produktion i prismodellen (p), som er opstillet på strukturel form (S) og interregional (ir). Det fremgår videre, at prisen på produktion er en funktion af en række eksogene pris- og omkostningselementer, som rækker fra prisen på den del af indkomsten, som fastsættes uafhængigt af prisen på det private forbrug, til prisen på import fra udlandet. Hertil kommer, at prisen på produktionen afhænger af en lang række transformationskoefficienter. Transformationskoefficienterne er hentet fra mængdemodellen.
Når modellen på strukturel form løses, fås følgende udtryk på reduceret form:

$$px = M^{R}_{pir}$$
$$= Multiplikator(D^{P}_{i,j}, T^{S,P}_{i}, d^{S,F}_{i}, S^{P,S}_{IC,i}, B^{P}_{IC}, b^{P}_{IC,i}, S^{R,S}_{CP,i}, B^{R}_{CP}, b^{R}_{CP,i}, H^{R}_{g,h}, J^{Q,R}_{g}, J^{P,Q}_{g}, Q^{P}_{j,g}, g^{P}_{j})$$
$$\bullet Eksogenevariabler(pz^{S,F}_{i}, pu^{P,F}_{IC,i}, pu^{R,F}_{CP,i}, pvx^{R}_{h}, pvx^{R}_{g}, pv^{P,F}_{g}, pvx^{P}_{j}) \text{.................................} (4)$$

Det fremgår her, at modellens løsning består af en multiplikator og en række eksogene variabler.

5.3. 2 x 2 x 2-princippet og typologi for regionale og lokale økonomier

I præsentationen af den generelle interregionale mængdemodel indgik etablering af en typologi til klassificeringer af lokalområder. Ser man på den generelle interregionale prismodel, fremgår det, at denne model understøtter klassificeringen forstået på den måde, at en multiplikator – både for pris- og mængdemodellen – bliver mindre jo større lækager. Dermed er klassificering af lokalområder også relevant, når omkostnings- og priseffekter studeres.

Til illustration heraf gås ud fra typiske lokale eller regionale udviklingsprojekter. Virkningen af et typisk projekt kan beskrives på to måder: Enten øges efterspørgslen efter en regions produkter direkte, eller også øges efterspørgslen indirekte gennem formindskelse af omkostninger og priser, som igen fører til øget eksport og mindsket import og dermed øget produktion, indkomst og beskæftigelse. I første tilfælde kan ræsonneres inden for mængdemodellen, mens andet tilfælde starter i prismodellen og afsluttes i mængdemodellen.

Ser man først på den direkte forøgelse af efterspørgslen efter et lokalområdes produkter, bliver de afledte virkninger eller mængdemultiplikatoren mindre, hvis den intraregionale handel, shopping, turisme og pendling for et lokalområde mindskes. Ser man dernæst på den indirekte forøgelse efter et lokalområdes produkter opnået gennem omkostnings- og prisreduktioner, bliver de afledte virkninger eller multiplikatoren også mindre, hvis den intraregionale handel, shopping, turisme og pendling for et lokalområde bliver mindre. Det skyldes, at konkurrenceevnevirkningerne i højere grad forsvinder ud af lokalområdet og dermed også de gunstige virkninger af lokale udviklingsprojekter på omkostninger og priser. Dermed mindskes de gunstige virkninger på eksport og import og dermed på produktion, indkomst og beskæftigelse.

5.4. Simultan løsning af den generelle interregionale mængde- og prismodel

Et centralt spørgsmål er, hvorledes den lokale økonomi beskrives, hvis der tages udgangspunkt i, at prissystemet påvirker mængdesystemet, og mængdesystemet påvirker prissystemet. Hvis den lokale økonomi skal beskrives mere udtømmende, skal der etableres links mellem de to systemer, hvorefter den simultane model søges løst. Som det fremgik ovenfor, præsenteres matematiske løsninger til de generelle interregionale mængde- og prismodeller separat for hver af modellerne. På grundlag af et meget simpelt link mellem ændringer i eksportmængder og -priser, præsenteres den simultane løsning for den lokale økonomi. Der redegøres for, at mulighederne for at finde en simultan løsning for den generelle interregionale mængde- og prismodel aftager, jo mere kompleks mængde- og prismodellen linkes sammen.

6. Demografi og lokaløkonomisk udvikling[27]

Et centralt problem, som netop udspringer af bestræbelserne for at finde en simultan løsning til den generelle interregionale mængde- og prismodel, er modellering af ændringer i den lokale og regionale økonomi. Ofte påvirker ændringer både økonomiens mængde – og prisdannelse. Modelmæssigt stiller det krav til sammenkædning af den generelle interregionale mængde- og prismodel. Hertil kommer, at transformationsmatricerne i de to submodeller ikke kan antages at være konstante. Til illustration præsenteres i ***afsnit 6*** en modelbaseret analyse af de lokale virkninger af den demografiske udvikling, som i de kommende år vil blive præget af befolkningens aldring. Modelteknisk opskrives den generelle

[27] Bjarne Madsen (2007): Modelling demography and the regional economy: An interregional general equilibrium modelling framework.

interregionale mængde- og prismodel i dette afsnit i ændringer, og der etableres links mellem de to submodeller til at illustrere virkningerne af demografiske forskydninger.

6.1. Den generelle interregionale mængde- og prismodel i differens

Som det fremgik af ***afsnit 4 og 5***, er fordelen ved at formulere den generelle interregionale model i niveau, at der kan afledes en matematisk løsning til modellen. Ulempen er, at det altovervejende er nødvendigt at antage lineære funktioner for at kunne løse modellen. Fordelen ved at formulere modellen i differens er, at der kan opereres med ikke-lineære funktioner, som formuleret i differens bliver lineære, som herefter kan løses. En yderligere fordel er, at man kan opfatte (en del af) løsningen til modellen i differens som multiplikatorer.

Inden for interregionale generelle ligevægtsmodeller er der tradition for at formulere modellerne i differens, således at det er muligt at tage hensyn til tilpasninger i produktion og forbrug, handelsstrukturer mv. Eksempel herpå er den australske MMRF-GREEN-model, jf. Peter m.fl. (2001) og Bröcker (1998). Det nye ved opskrivningen af den generelle interregionale mængde og prismodel er, at formuleringen omfatter den lokale økonomi, hvor modellering baseres på 2 x 2 x 2-princippet.

Konkret opskrives alle ligninger i mængde- og prismodellen i differens, som løses som to submodeller, på samme måde som modellen blev løst i niveau – jf. ***afsnit 4 og 5***. Forinden foretages ændringer i udvalgte dele af modellen for at afspejle problemstillingen omkring sammenhængen mellem lokaløkonomi og demografisk udvikling.

For det første antages, at erhvervsfrekvensen (deltagelsesfrekvensen for arbejdsstyrken) påvirkes af den gennemsnitlige indkomst, således at ændringer i erhvervsfrekvensen afhænger af ændringer i gennemsnitsindkomst for de respektive aldersgrupper, det vil sige et fald i gennemsnitsindkomsten medfører et fald i erhvervsfrekvensen.

For det andet antages produktiviteten at afhænge af den aldersmæssige sammensætning af beskæftigelsen inden for de respektive erhverv. En aldring af de beskæftigede i et erhverv antages at sænke produktiviteten.

For det tredje antages den aldersmæssige sammensætning af beskæftigelsen inden for de respektive erhverv at afhænge af de relative gennemsnitsindkomster. Hvis gennemsnitsindkomsten for en given aldersgruppe vokser relativt i forhold til andre aldersgruppers gennemsnitsindkomst, falder andelen af beskæftigede i den givne aldersgruppe i de respektive erhverv.

Endelig antages, at indkomstændringer afhænger af forskellen mellem lokalområdets arbejdsløshed og den naturlige arbejdsløshed for lokalområdet.

6.2. Aldring og lokaløkonomisk udvikling

Med udgangspunkt i modellen gennemføres en analyse af aldringens lokaløkonomiske virkninger på kort og længere sigt. Aldring betyder initialt et fald i arbejdsløsheden for både de yngre og de ældre aldersgrupper – for begge grupper relativt i forhold til den naturlige arbejdsløshed, som antages at være i ligevægt i udgangssituationen. Den faldende arbejdsløshed fører alt andet lige til relativt højere lønstigninger og dermed voksende eksportpriser og dermed faldende eksport. Faldende eksport betyder nedgang i efterspørgsel, produktion, indkomst og beskæftigelse. Arbejdsløsheden, som faldt initialt, vil herefter vokse igen og tilpasses i retning af den naturlige arbejdsløshed. På længere sigt vil arbejdsløsheden være tilbage på den naturlige arbejdsløshed, produktiviteten på et lavere niveau, og dermed højere priser, lavere eksport og højere import og lavere produktion, indkomst og beskæftigelse.

Regionalt er virkningerne forskellige og følger den typologi, som blev etableret i forbindelse med præsentationen af den generelle interregionale mængdemodel. Effekterne afhænger herefter af aldringens direkte effekter for lokalområder og multiplikatorerne for forskellige typer lokalområder, herunder hvorvidt aldringen har en betydning for multiplikatorernes størrelse.

7. LINE – en lokaløkonomisk model for danske kommuner[28]

LINE er udviklet i slutningen af 1990'erne og begyndelsen af årtusindskiftet. LINE er unik, fordi den giver en i international sammenhæng hidtil uset detaljeret beskrivelse af den økonomiske aktivitet i den lokale økonomi. Udviklingen af LINE var i høj grad styret af strukturen i den generelle interregionale mængde- og prismodel, dvs. 2 x 2 x 2-princippet. Desuden afspejler LINE de datamæssige muligheder i den danske regional- og lokaløkonomiske statistik, ligesom udviklingen af LINE trækker på erfaringer med AIDA[29], som var en interregional model for danske amter. Modellen blev udviklet i slutningen af 1980'erne og begyndelsen af 1990'erne. LINE er dokumenteret i Madsen m.fl. (2002a) og Madsen og Jensen-Butler (2005).

7.1. Fra AIDA til LINE

Hvis strukturen i AIDA benyttes som udgangspunkt for beskrivelsen, kan udviklingen fra AIDA til LINE beskrives således:

For *det første* repræsenterer LINE en overgang fra modellering af økonomisk aktivitet på amter til fleksible geografiske enheder, fx kommuner, pendlingsoplande eller kommuner opdelt på subkommunalt niveau.

For *det andet* sker en overgang fra anvendelse af institutionelle input-output-modeller til strukturelle input-output-modeller. I den internationale tradition baseres regionaløkonomiske modeller i høj grad på den institutionelle tilgang, hvor det økonomiske samspil mellem erhverv modelleres som et direkte samspil mellem erhverv, udtrykt i den institutionelle eller sektor gange sektor input-output-model. Med fremkomsten af regionale og interregionale SAM'er er det blevet naturligt i stedet at arbejde med to input-output-matricer til sammenkædning af samspillet mellem erhverv. Her indgår dels make-matricen, som viser, hvilke varer der produceres af et givet erhverv, og use-matricer, som viser, hvilke (rå)varer som erhverv efterspørger, og hvilke (forbrugs)varer som institutioner (fx husholdninger) efterspørger. I Madsen og Jensen-Butler (1999b) argumenteres for, at opsplitningen af input-output-modeller i to delmodeller er teoretisk mere tilfredsstillende og tættere på data, som indsamles af statistikbureauer til brug for opstilling af (nationale) input-output-tabeller.

For *det tredje* anvendes tre geografiske begreber – produktionssted, bopæl og varemarkedssted[30] – modsat AIDA, hvori der kun indgår produktionssted.

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[28] Bjarne Madsen og Chris. Jensen-Butler (2004): *Theoretical and operational issues in sub-regional modelling, illustrated the development and application of the LINE Model*. Economic Modelling, Volume 21, Issue 3, p. 471-508.
[29] En dokumentation af AIDA er givet i Madsen (1992) og Jensen-Butler og Madsen (1996).
[30] I nogle af de første præsentationer af LINE betegnes varemarkedssted som efterspørgselssted.

For *det fjerde* indgår i LINE desuden en SAM-akse med erhverv, typer af arbejdskraft, typer af husholdninger og grupper af varer. I forhold til AIDA er der tale om en kraftig udvidelse af beskrivelsen af økonomisk aktivitet, hvor der alene indgik en opdeling i erhverv.

For *det femte* modelleres interregional (og international) handel i varer, hvor der i AIDA var tale om modellering af handel i erhverv. Denne udvikling repræsenterer på den en side en teoretisk forbedring, idet varehandel – som ordet siger – foregår i varer. Samtidig medfører overgangen til varer, at modellen forenkles, idet leverancer mellem erhverv og slutbruger opdeles i tre rene trin: Fra erhverv til vare (use-matricen), fra varemarkedssted til produktionssted (handel) og fra varer til erhverv (make-matricen). I den institutionelle tilgang, som benyttes i AIDA, etableres et samspil mellem hvert leverende erhverv og hvert modtagende erhverv/slutbruger, hvilket i tilfælde med flere end en halv snes regioner giver ekstremt mange handelsflow og deraf afledt krav til data.

For *det sjette* modelleres handelsmarginaler[31] og vareskatter[32] i LINE eksplicit og knyttet til varer og anvendelse. Heraf beregnes anvendelse i køberpriser henholdsvis basispriser. Geografisk knyttes modelleringen til varemarkedssted. I forhold til AIDA er der tale om en teoretisk mere tilfredsstillende og enklere modellering, ligesom datakrav er mindre trods den kraftigt udvidede modellering.

For *det syvende* modelleres erhvervs- og lønindkomster, indkomstoverførsler og skatter meget mere detaljeret og opdelt på typer af arbejdskraft og familietyper.

For *det ottende* modelleres privat forbrug opdelt på lokalt privat forbrug og på turistindtægter. Det lokale private forbrug er opdelt på bopæl og varemarkedssted og varetyper, mens turistindtægterne fra danskere, som er på ferie i Danmark, og udenlandske turister er opdelt efter turistkategori (hotelgæster, campister mv.) og bopæl/hjemland. I AIDA var der ikke en endogen modellering af indenlandsk turisme.

7.2. Fra den generelle interregionale model til datamuligheder

Udviklingen af LINE måtte nødvendigvis tage hensyn til datamuligheder. Hermed fulgte LINE ikke fuldt ud strukturen i den generelle interregionale model. Der kan fremhæves følgende tilpasninger, som afspejler begrænsninger i data, hvoraf nogle afspejler udbygninger og andre simplificeringer af det generelle 2 x 2 x 2-princip.

For det første indgår begrebet faktormarkedssted ikke, fordi der i statistikken ikke indgår et sådant begreb. I praksis kan bopæl for en produktionsfaktor tolkes som faktormarkedssted. Fra et datasynspunkt kan kun produktionsfaktorens bopæl og produktionssted registreres og faktormarkedsstedet indgår derfor ikke i LINE.

For det andet er det kun den del af bruttoværditilvæksten, som tilfalder personer (dvs. primærindkomsten), som følges videre gennem pendling, personbeskatning mv. På sigt vil selskabsindkomst mv. kunne få samme behandling som primærindkomst, hvis informationer fra indkomstsystemet kan fremskaffes. Ligeledes vil der kunne etableres en relation mellem (brutto)investeringer og opsparing.

[31] Handelsmarginaler er opdelt i detailhandels- og engroshandelsmarginaler.
[32] Vareskatter er opdelt i moms og andre vareskatter.

For det tredje er der et behov for at belyse samspillet mellem institutioner, som fx husholdninger, den offentlige sektor og firmaer. I LINE indgår samspillet mellem husholdningssektoren og det offentlige (fx skatter, indkomstoverførsler) bl.a. for at kunne vurdere husholdningernes økonomiske styrke, fx ved opgørelse af den disponible indkomst. Derfor indgår i LINE interaktionen mellem produktionsfaktor, husholdninger og den offentlige sektor.

For det fjerde indgår i LINE en to-steps procedure for modellering af det private forbrug: For det første træffer husholdninger – geografisk henregnet til bopæl – beslutninger vedr. private forbrug for varegrupper. For det andet foretages en mere specifik fordeling af det private forbrug på varer på varemarkedsstedet, hvor beslutningen om fordeling af forbruget på varer foretages. Denne nesting af beslutninger vedr. det private forbrug indgår i LINE, fordi de nationale data, som benyttes som overliggende ramme for estimation af varebalancerne, har en nestet struktur. Den samme nesting indgår for andre typer anvendelse, fx det offentlige forbrug, hvor beslutninger om offentlig service på aggregeret niveau træffes på bopæl, hvor der sker en tildeling af offentlig service, mens beslutninger om fordeling på detaljerede varegrupper sker på varemarkedssted henholdsvis produktionssted (offentlige servicevarer samt offentligt råvareforbrug fordelt på varer).

For det femte er det private forbrug i LINE opdelt i lokalt privatforbrug og i turisme. Denne opdeling er benyttet i forskellige analyser af turismens regionaløkonomiske betydning, hvor det udnyttes, at der i LINE sondres mellem danskeres turisme i Danmark og i udlandet, mens udenlandsk turisme i Danmark inddeles i endagsturisme og overnatningsturisme.

For det sjette indgår forskellige værdibegreber i LINE. For varer anvendes køberpriser eller markedspriser i værdiopgørelsen, dvs. priser inkl. vareskatter og handelsavance. Udbuddet af varer opgøres i basispriser på produktionsstedet og frem til varemarkedsstedet, hvor prisen tillægges vareskatter og handelsavancer. Interregional handel opgøres herefter i basispriser. Basispriser defineres som værdien af produktionen ab fabrik, ekskl. vareskatter, netto betalt af producenten.

Endelig indgår forskellige prisniveauer i LINE, dvs. faste og løbende priser. LINE består af en interregional mængdemodel og prismodel. I mængdemodellen opgøres produktion og efterspørgsel i faste priser, mens prismodellen indeholder prisindeks for produktion og efterspørgsel. På grundlag af mængdemodellens oplysninger om produktion og efterspørgsel i faste priser og prismodellens prisindeks kan produktion og efterspørgsel i årets priser beregnes implicit.

7.3. Anvendelser af LINE

I Madsen og Jensen-Butler sammenfattes resultater af 10 forskellige anvendelser af LINE. Centralt i præsentationen er, at LINE kan konfigureres i overensstemmelse med de konkrete analysebehov. Se tabel 3.

Af tabellen fremgår for det første den geografiske enhed, som hver analyse anvender (kommuner, amter eller pendlingsoplande). Dernæst angives det, hvorvidt den version af LINE, som anvendes, analyserer på produktionssted, bopæl henholdsvis varemarkedssted. Nogle af de første analyser baseret på LINE er begrænset til produktionssted og bopæl, mens stort set alle senere analyser i geografisk henseende har fuldt udbyggede analyser. Dernæst angives, hvorvidt der benyttes en opdeling af økonomiske aktiviteter efter en Social Accounting Matrix-specificering. For det første indgår erhverv i de fleste analyser. I mere udbyggede og senere analyser indgår tillige en opdeling af økonomisk aktivitet efter typer af produktionsfaktorer, efter type husholdning og efter varegrupper. Specielt opdeles beskæftigelse og personlige indkomster efter alder, køn og uddannelse.

Videre oplyses, hvilke dele af LINE som medtages, dvs. hvorvidt mængde- henholdsvis prismodellen indgår, hvor i visse tilfælde alene "mængdemodel I", som vedrører modellering af primærindkomst og beskæftigelse efter arbejdssted henholdsvis bopæl samt på grundlag heraf beregning af skatter og indkomstoverførsler, indgår, mens "mængdemodel I & II" indgår i udbyggede versioner af LINE. Endelig angives, hvorvidt mængde og prismodellen er linket sammen gennem relationer mellem efterspørgsel (fra mængdemodellen) og priser (fra prismodellen).

Til slut angives, hvorvidt modelanalyserne, der er "top-down", benytter overordnede nationale eller internationale analyser som udgangspunkt for nedbrydning af resultater til det regionale og lokale niveau eller "bottom-up", som baseres på detaljerede modelberegning for små enheder, som herefter aggregeres op til samlede nationale resultater.

Tabel 3. Eksempler på studier, hvori indgår anvendelse af LINE

Studier	Regioner:				SAM-komponenter							Modelcirkler				Modelhierarki	
	Regionalt niveau	Produktionssted	Bopæl	Varemarkedssted	Erhverv	Faktorer: Alder	Køn	Uddannelse	Institutioner	Behov	Varer	Mængdemodel I	Mængdemodel II	Prismodel	Links mellem 2 submodeller	Top-down	Bottom-up
Landdistriktsudvikling/scenarier																	
Landdistrikternes udvikling[1)]	Kommuner	X	X		X				X			X					
Landbrugs- og miljøregulering[2)]	Kommuner	X	X	X	X				X	X	X	X	X			X	
Industriens udvikling[3)]	Kommuner	X	X	X	X				X	X	X	X	X				
Turisme[4)]	Amter	X	X	X	X	X	X	X	X	X	X	X	X				
Bosætning[5)]	Kommuner	X	X	X	X	X	X	X	X	X	X	X	X				
Velfærdsscenario[6)]	Kommuner	X	X		X				X			X				X	
Andre analyser:																	
Hovedstandens udvikling[7)]	Kommuner	X	X		X				X			X					
Roadpricing[8)]	Amter	X	X	X	X				X	X	X	X	X	X			
Storebæltstakster[9)]	Amter	X	X	X	X				X	X	X	X	X	X	X		
Indkomstvækst-dekomponering[10)]	Pendlings-oplande	X	X	X	X	X	X	X	X	X	X	X	X				
Arbejdsmarked[11)]	Amter	X	X	X	X	X	X	X	X	X	X	X	X			X	
Ny økonomi – hovedstaden[12)]	Amter	X	X	X	X	X				X	X	X	X				

1) Jensen-Butler m.fl. (2002)
2) Hasler m.fl. (2002)
3) Andersen & Christoffersen (2002)
4) Zhang (2001)
5) Andersen (2002)
6) Dam m.fl. (1997)
7) Expert Committee (1998)
8) Madsen & Jensen-Butler (2001)
9) Madsen m.fl. (2002)
10) Madsen and Jensen-Butler (2005)
11) Lundtorp m.fl. (2005)
12) Telle & Tanghøj (2002)

8. Systemtilgange til modellering af regional- og lokaløkonomisk udvikling[33]

Når modeller benyttes i analyser af regionale eller lokale økonomier, er analysen ofte begrænset af den regionale eller lokaløkonomiske model. Tillige er det ofte nødvendigt med mere detaljerede modeller – fx for landbrugsproduktionen – for at belyse konsekvenserne fyldestgørende Overordnet betragtet er der således behov for en systemtilgang, som vertikalt[34] inkluderer virkninger fra det internationale niveau på lavere geografiske niveau, virkninger fra det nationale niveau til det regionale og lokale niveau og endelig fra det regionale til det lokale niveau. Horisontalt er der behov for at se på virkninger mellem økonomiske konsekvenser for den lokale økonomi henholdsvis for specifikke erhverv eller varer. Der kan fx være tale om virkninger for transportvaren af ændringer i interregional varehandel, af pendling, shopping og turisme. Eller det kan være virkninger mellem landbrugserhvervet og den øvrige del af den regionale og lokale økonomi.

8.1. Modelsystem

Behovet for anvendelse af et bredere og større modelsystem rejses i flere forskellige analyser. Inden for transportområdet redegøres for, at der er et samspil mellem transportsektoren og den (inter)regionale økonomi. I Madsen og Jensen-Butler (1991) beskrives i en analyse af de regionale konsekvenser af en fast Storebæltsforbindelse efterspørgslen efter transport som afledt efterspørgsel, således at behovet for transport i høj grad bestemmes af den regionale og lokale økonomiske udvikling.

I Madsen og Jensen-Butler (1999a) anvendes forskellige kvantitative modeller til belysning af de regionale konsekvenser af en fast forbindelse over Femern Bælt. Valget af en ”eklektisk tilgang”, hvori indgik forskellige modeller, som ikke hviler på samme teoretiske udgangspunkt, og som kan være indbyrdes inkonsistente, er naturligvis ”second best”. Men da der er en stor interesse for at få konsekvenserne belyst af etablering af en fast Femern Bælt-forbindelse og da der ikke fandtes et samlet konsistent modelsystem, som kunne belyse samspillet mellem regional og lokaløkonomi henholdsvis transportsystem, blev en eklektisk tilgang valgt.

Som konsekvens heraf anvendtes forskellige modelværktøjer:

a) Trafikmodel for trafik mellem Skandinavien og kontinentet.
b) Enregionsmodel for økonomisk aktivitet i Storstrøms Amt – EMIL-modellen.
c) AIDA- interregional model for danske amter.
d) Potentialemodel til belysninger af ændringer i konkurrenceevnen for forskellige regioner i Europa.

Dette sæt af modeller benyttedes til at beregne konsekvenser for produktion, indkomst og beskæftigelse regionalt såvel som lokalt af

1) erstatning af færge med fast forbindelse (EMIL),

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[33] Bjarne Madsen, Chris Jensen-Butler, Steen Leleur og Jacob Kronbak (2007): *A Systems Approach to Modelling the Regional Economic Effects of Road Pricing*. I "Traffic, Road Pricing and the Environment" i serien "Advances in Spatial Science", udgivet af Springer.

[34] I argumentationen er det forudsat, at systemet er top-down- modsat bottom-up systemer, hvor det lokale og regionale niveau bestemmer de højere niveauer. En alternativ tilgang er at se på mikro- og makroniveauet, hvor makro-niveauet i top-down approachet bestemmer mikroniveauet, mens mikroniveauet i bottom-up approachet bestemmer makroniveauet. I begge tilfælde kan man også forestille sig integrerede approaches, hvor der er tale om vekselvirkninger mellem de to niveauer.

2) omlægning af korridortrafikken fra de svenske Østersøruter og Jyllandskorridoren til Femern Bælt-korridoren (trafikmodel og EMIL),
3) øget aktivitet i overnatnings- og restauranterhvervene (trafikmodel henholdsvis EMIL),
4) forbedret og forringet tilgængelighed for forskellige regioner i Skandinavien og på kontinentet (potentialemodel og AIDA).

Resultatet af delanalyserne blev – i mangel af et samlet konsistent analyseværktøj – lagt sammen for at illustrere den samlede effekt.

Overvejelser vedrørende opbygning af et samlet integreret modelsystem til evaluering og fremskrivning af regional udvikling og transportinfrastruktur blev udbygget i Madsen (2000) og Madsen og Jensen-Butler (2001), hvori der blev beskrevet krav til data og modeller i en ex post-evaluering af den fast Øresundsforbindelse.

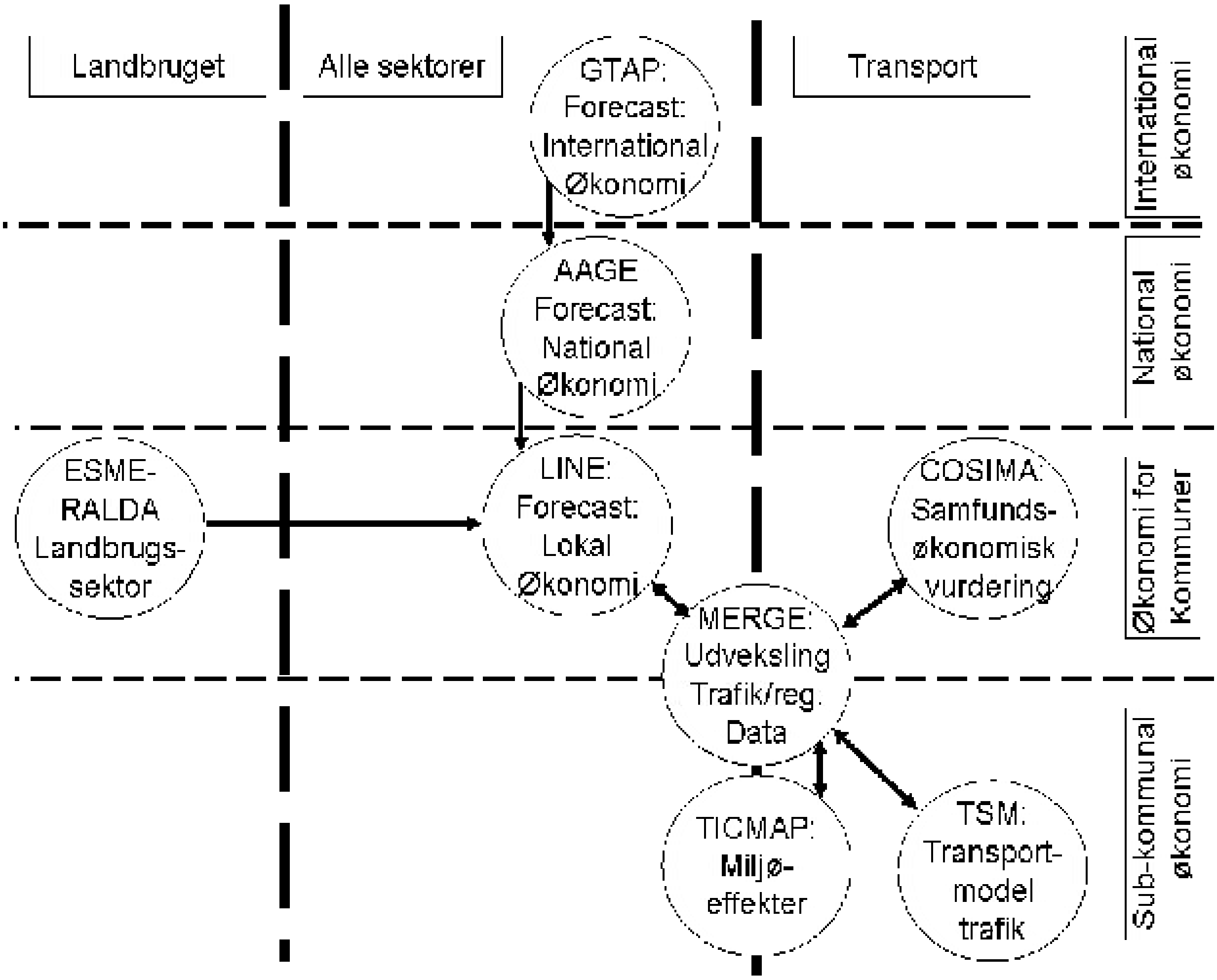
I Hasler m.fl. (2002) præsenteres analyser af den regionale udvikling i landbruget og den overordnede regionale udvikling. I disse analyser anvendes sektormodeller for landbruget (ESMERALDA) og generelle modeller (GTAP, AAGE, LINE). Der præsenteredes resultater af fremskrivning og konsekvensanalyse for jordbruget og den lokale økonomi med et samlet modelsystem for international, national, regional og lokal udvikling, herunder samspillet mellem landbruget og den øvrige økonomi på alle de nævnte niveauer.

I Madsen m.fl. (2007) beskrives et samlet modelsystem, som består af følgende delmodeller (se figur 3).

Af figuren fremgår, at modelsystemet vertikalt beskriver det internationale, nationale, regionale (kommuner) og lokale niveau, mens figuren horisontalt beskriver sektor-afgrænsning af modelsystemet.

I Madsen m.fl. (2007) benyttes modelsystemet til belysning af de regionale konsekvenser af roadpricing. I analysen indgår anvendelse af transportmodeller til belysning af konsekvenser for transportomkostninger af indførelse af roadpricing. Med udgangspunkt heri beregnes med LINE de lokaløkonomiske konsekvenser af ændrede transportomkostninger.

Figur 3. Sammenkædning af danske modeller af forskellig type og på forskellige niveauer



8.2. Overvejelser vedr. strukturen af et modelsystem

I forbindelse med præsentationen af modelsystemet overvejes, hvorledes et modelsystem sættes sammen afhængig af analysespørgsmål. Samspillet mellem regional udvikling og transport er anvendt som case til illustration af problemstillingerne.

Der opstilles forskellige standardkonfigurationer af modelsystemer:

a) Udvidelse af sektormodeller.
b) Udvidelse af regionale og subregionale modeller.
c) Løst koblede modeller.
d) Fuldt integrerede modeller.

Den første tilgang kan illustreres med transportmodeller, hvor udgangspunktet i modeludviklingen er transportspørgsmålet, som herefter bliver omdrejningspunktet for analyser af den regionale og lokale udvikling. Der advares mod, at udvidelse af sektormodeller som metode kan indebære en risiko for bias i retning af overdrivelse af sektorens betydning.

Den anden tilgang, hvor der alene tages udgangspunkt i generelle økonomiske modeller, kan illustreres med analyser af regionale virkninger af trafikinfrastruktur. Selv om forskydning i interregional handel, pendling, shopping mv. har betydning for udvikling i trafikken, er det utvivlsomt nødvendigt at inkludere analyser af mere trafikteknisk art, som fx valg af transportmåde, -rute mv. for at opnå det fulde billede af konsekvenserne for trafikstrømme og transportomkostninger og dermed konsekvenserne for den regionale økonomi.

Den tredje tilgang tager udgangspunkt i den praktiske analysesituation, hvor der ofte vil være generelle økonomiske og sektorspecifikke modeller, som kan belyse virkninger for regional udvikling og transport. Der skal her tages stilling til, hvilke modeller som skal indgå i analyserne, samt hvorledes modellerne indbyrdes skal samarbejde.

Endelig er der de fuldt integrerede modelsystemer, hvor modellen benytter fælles datagrundlag, og modellen løses samlet, og det forudsættes, at delmodellerne har samme teoretiske udgangspunkt, og løsningen repræsenterer et samlet afstemt system.

8.3. Løst koblede systemer

Da det er de løst koblede systemer, som p.t. er udgangspunktet i den praktiske planlægningssituation, har det betydning at se nærmere på de valg, som træffes ved opbygning af sådanne systemer.

Et centralt spørgsmål er det indbyrdes hierarki mellem delmodellerne, som skal bestemmes. Her kan relationen mellem en sektormodel og en generel økonomisk model beskrives som en formodel-, eftermodel- eller simultantilgang. I Madsen m.fl. (2007) er ambitionen at etablere en simultan regneprocedure, således at transportmodellen og den lokaløkonomiske model regner et antal gange for at finde en samlet simultan ligevægt. I praksis blev resultatet, at der i modelberegningerne kun blev anvendt formodel-tilgang. Det skyldes projektets begrænsede ressourcer samt utvivlsomt vanskeligheder ved at beskrive tilbagevirkninger fra den generelle regionale økonomi til transportsektoren.

I ”formodel-tilgangen” tages udgangspunkt i transportmodellen som formodel, der beregner de generaliserede transportomkostninger (med og uden roadpricing). Transportomkostningerne benyttes herefter som input i den generelle lokaløkonomiske model[35], som på grundlag af ændringer i transportomkostningerne beregner påvirkning af omkostninger og priser, som herefter påvirker mængdemodellens bestemmelse af efterspørgsel, produktion, indkomst og beskæftigelse.

8.4. Perspektiver

På længere sigt vil integrerede modelsystemer være mest tilfredsstillende. Umiddelbart forekommer det imidlertid som en umulig opgave, da det vil forudsætte meget store datasystemer og meget komplekse modelsystemer, som er vanskelige at løse. Uden at gå i detaljer forekommer introduktion af mikrosimuleringsmodeller, som på mikroplan indeholder modellering af (en lang række) beslutninger for individer og produktionsenheder, som den realistiske udvej, hvis det i fremtiden skal være muligt at modellere den lokale økonomi i hele sin totalitet.

[35] Detaljer præsenteres i artiklen og i senere afsnit i denne sammenfatning.

C. Det generelle lokale samfundsregnskab – SAM-K

På samme måde som de lokale modeller indeholder en i international målestok unik beskrivelse af den økonomiske aktivitet, indeholder de lokale nationalregnskaber, som modellerne benytter som datagrundlag, en hidtil uset beskrivelse og detaljering, ligesom principperne for opstilling af nationalregnskaberne repræsenterer et unikt bidrag til arbejdet på dette område.

9. Lokalt samfundsregnskab – SAM-K[36]

Til regional- og lokaløkonomiske analyser benyttes data dels til afgrænsede analyser af enkelte spørgsmål dels til analyser, som fokuserer på samlede virkninger for den lokale økonomi. Data forefindes som enkeltstående, uafhængige datasæt eller organiseres i lokale samfundsregnskaber eller nationalregnskaber.

Formålet med at integrere data i lokale samfundsregnskaber er – ud over at skabe overblik over den lokale økonomi – at sikre kvaliteten af data, fx gennem sikring af overholdelse af bogholderimæssige identiteter. Bogholderimæssige identiteter skal være opfyldt for individuelle enheder (producenter og husholdninger), på mesoniveau (fx skal gælde at summen af interregional eksport er lig summen af interregional import) og på makroniveau (det samlede udbud af en vare er lig den samlede efterspørgsel). Hvis der ved opbygningen af data ikke kontrolleres for konsistens i uafhængige datasæt, risikerer man at drage fejlslutninger, fordi data ikke er sammenlignelige og "stemmer", hvis de lægges sammen.

9.1. Baggrund

I Danmark har der været arbejdet med opstilling af regionale nationalregnskaber i 35 år. De første forsøg blev gjort for Sønderjylland (Damgård m.fl. 1983). Senere blev opstillet regionalregnskaber for alle amter (Ahmt og Madsen 1997).

I midten af 1990'erne blev der skabt økonomisk mulighed for at opbygge lokale samfundsregnskaber for kommuner, hvilket skete i et samarbejde mellem AKF og Danmarks Statistik. Arbejdet er dokumenteret i Madsen m.fl. (2002b)[37] og Madsen og Jensen-Butler (2005). SAM-K indgår i dag som database for danske regioner og beskæftigelsesregioner m.fl. som led i en overvågningsmodel, hvor data vedr. lokal produktion mv. benyttes som grundlag for vurdering af den økonomiske udvikling på lokalt plan.

9.2. 2 x 2 x 2-princippet

Princippet bagved det lokale samfundsregnskab (SAM-K) er det såkaldte 2 x 2 x 2-princip. Princippet, som også anvendes i forbindelse med den generelle interregionale mængde- og prismodel, kan illustreres af figur 1 og 2:

For *det første* indgår i det lokale samfundsregnskab den økonomiske aktivitet for to agenter, producenter (Pj) og institutioner (Rh). I SAM-K indgår i princippet en mikroregistrering af økonomisk aktiviteter for produktionsenheder og husholdninger (institutioner).

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[36] Madsen, Bjarne og Chris Jensen-Butler (2005): Spatial Accounting Methods and the Construction of Spatial Accounting Matrices. *Economic Systems Research, vol 17, No. 2, p. 187-210.*

[37] Afsnit 4 i Madsen m.fl. (2002b) indeholdt Danmarks Statistiks dokumentation af arbejdet med opstilling af kommunefordelte tal for produktion.

For *det andet* indgår i den lokale økonomi to markeder, varemarkedet og faktormarkedet. I SAM-K indgår i princippet en mikroregistrering af produktion og efterspørgsel for varer henholdsvis af indkomst (og beskæftigelse) for typer af produktionsfaktorer.

For *det tredje* eksisterer en geografisk sammenbinding af udbud og efterspørgsel for de to markeder. For faktormarkedet er der tale om pendling, mens der for varemarkedet er tale om varehandel og shopping.

9.3. Dataindsamlings- og kalibreringsmetoder

I SAM-K indgår en blanding af bottom-up og top-down data. *Bottom-up data* baseres på register-/administrative data eller totaltællinger, som herefter summeres til makrodata i det lokale samfundsregnskab. Der er tale om data for *faktormarkedet*, dvs. erhvervenes efterspørgsel efter produktionsfaktorer og husholdningernes udbud af produktionsfaktorer. Erhvervenes efterspørgsel efter produktionsfaktorer er opdelt efter erhverv og typer af produktionsfaktorer og henregnes til produktionssted. Husholdningernes udbud af produktionsfaktorer er opdelt på familietyper og typer af produktionsfaktorer og henregnes til bopælen.

I *top-down data* anvendes en kombination af et afstemt nationalregnskab for hele landet, data for produktion i lokalområderne og diverse surveys for økonomisk aktivitet i lokalområdet. Der estimeres tal for tilgang, hvilket dækker produktion og import fra udlandet, og anvendelse, hvilket dækker lokal efterspørgsel og eksport til udlandet. Ved estimation af produktion fordelt på erhverv og varer indgår lokale data for produktion opgjort efter produktionssted og nationale data for erhvervenes produktion fordelt på varer. Importen fra udlandet estimeres ud fra data for lokal efterspørgsel fordelt på varer og nationale importandele.

I estimationen af anvendelse indgår data fra Danmarks Statistik vedr. erhvervenes råvareforbrug, registerdata vedr. disponibel indkomst og surveydata vedr. privatforbrug, data vedr. lokal produktion af offentlige servicevarer til brug ved estimation af offentligt forbrug og investeringer, mens der ved estimation af eksport til udlandet anvendes nationale data vedr. varefordelt eksport samt produktionsdata.

Da kvaliteten af registerdata kan anses for at være i top, sker der alene en afstemning i varebalancen, mens faktorbalancen er udgangspunktet for estimationen af varebalancen. For varebalancen tages udgangspunkt i den nationale varebalance[38]. I Madsen og Jensen-Butler (2005) præsenteres den lokale varebalance, som herefter opdeles i en betalingsbalance, som herefter underinddeles i en varebalance, pendlingsbalance, en shopping- og turistbalance samt en offentlig balance.

9.4. Perspektiver

Anvendelse af et bottom-up princip både for faktor- og varemarkedet på grundlag af registerdata er fremtiden. Anvendelse af register- eller administrative data kombineret med totaltællinger for faktormarkedet, som det sker ved opstillingen af SAM-K, er således et første skridt i retning af opstilling af hele nationalregnskabet ud fra registerdata. Hvor det lokale nationalregnskab i dag alene afstemmes for varebalancen, vil et system, som benytter registerdata for både faktor- og varebalancen, skulle afstemmes på en anden måde. Her kan man ikke automatisk gå ud fra, at fejl ligger i estimation af varebalance – og det kan således komme på tale at tilpasse både faktor- og varebalance.

[38] Den nationale varebalance er opstillet i såkaldte tilgangs- og anvendelsestabeller, hvor tilgangen på nationalt plan er afstemt med anvendelsen på nationalt plan.

10. Principper bag opbygning og sikring af data af høj kvalitet i SAM-K[39]

Da der ikke på alle områder eksisterer register- eller administrative data eller totaltællinger, har der været behov for at udvikle og anvende arbejdsprincipper til dannelse af SAM-K, som sikrer, at data opfylder basale konsistenskrav og arbejdsmetoder, som sikrer højere kvalitet af data, uden at der eksisterer konkrete observationer på mikroplan. I ***afsnit 10*** – jf. Madsen og Jensen-Butler (1999b) – argumenteres for, at estimation af data i lokalt samfundsregnskab bør ske på det mest detaljerede niveau, og at man bør benytte identiteter for udbud og efterspørgsel efter varer for at sikre, at data overholder basale bogholderimæssige restriktioner.

I Jensen-Butler m.fl. (2003) gennemføres en analyse af kvaliteten af forskellige procedurer til estimation af intra- og interregional handel, hvoraf fremgår, at en dis-aggregeret procedure[40] sikrer data af højere kvalitet, hvis handelsstrukturen for givne varer/varegrupper er lokal, dvs. der leveres varer mellem kommuner i lokalområdet, mens der ikke er væsentlige kvalitetsgevinster at hente, hvis handelsmønstret for de givne varer/varegrupper er interregionalt eller internationalt.

[39] Bjarne Madsen og Chris Jensen-Butler (1999): Make and Use Approaches to Regional and Interregional Accounts and Models. *Economic Systems Research. Vol. 11, No. 2, p. 277-299.*

[40] En disaggregeret procedure til estimation af regionale handelsdata består i anvendelse af kommunale data for tilgang og anvendelse, hvorefter handelsmønstret på regionalt niveau aggregeres på grundlag heraf. Modsat indgå i en aggregeret procedure alene regionale data, hvor handelsdata estimeres på regionalt niveau uden hensyntagen til at der findes detaljerede data på kommunalt niveau.

D. Regionale konsekvenser af transportinvesteringer og -regulering

En central del af modeludviklingen har haft sit udspring i analyser af de regionale og lokale konsekvenser af transportinvestering og – på det seneste – regulering af trafiksystemet – fx vejafgifter. I projekter gennemført i 1990'erne var det naturligt virkningerne af de tre faste forbindelser over Storebælt, Øresund henholdsvis Femern Bælt, som var i fokus. Udgangspunktet var således en kombination af ønsker fra politisk og administrativt niveau om at få information om bl.a. de forventede regionale og lokale virkninger af disse store projekter og af forskningsmæssig interesse i at udvikle analyseredskaber til at forstå samspillet mellem trafikinvesteringer og regional og lokal udvikling[41]. I de sidste 10 år har det mere været ønsket om at opnå viden om virkningerne af regulering af transportsystemet og især vejafgifter.

Nedenfor er givet en overblik over resultaterne af analyserne, strukturen af den eller de modeller, som er anvendt i de respektive analyser, samt samspillet mellem resultater og modelstruktur.

11. Den faste Storebæltsforbindelse[42]

De regionale konsekvenser af den faste Storebæltsforbindelse er analyseret i forskellige rapporter og artikler (Madsen 1992; Madsen og Jensen-Butler 1991; 1992 og Jensen-Butler og Madsen 1996/2004). De samlede virkninger skønnes at være ca. 2000 arbejdspladser. Største gevinster opnår hovedstadsområdet og Vestsjælland og Fyn, som forbindes af Storebæltsforbindelsen, mens perifert beliggende regioner set i relation til Storebæltsforbindelsen – især Nordjyllands Amt, som stort set ingen transportmæssige gevinster opnår på Kattegatruterne – ingen fordele opnår. Den begrænsede virkning skal ses i sammenhæng med den model som anvendes i analysen (AIDA-modellen), og de effekter, som er medtaget i analysen.

Analysen, som præsenteres, er en ex ante-analyse, som viser de forventede effekter, før forbindelsen etableres. Der ses på effekterne for den regionale konkurrenceevne og indeholder virkningen for regional eksport og import, mens andre virkninger – som fx konsekvenser af nedlæggelse af færgetrafikken, af omlægning i trafikstrømmene fra Kattegatruterne til Storebæltsforbindelsen ("trafikkorridoreffekter") – ikke medtages i analysen. Modellen AIDA (Madsen 1992), som anvendes, og som blev opbygget som led i analysen, er en interregional mængdemodel af den såkaldte Isard-type, hvor den regionale input-outputmodel er institutionel, dvs. sektor gange sektor:

[41] I Madsen m.fl. (1993) er givet et overblik over udenlandske undersøgelser af regionale konsekvenser af trafikinvesteringer.

[42] Jensen-Butler, Chris og Bjarne Madsen (1996, 2004): Modelling the Regional Economic Effects of the Danish Great Belt Link. Papers in Regional Science: *The Journal of the RSAI* 75, 1: pp. 1-21 and In: *Classics in Transport Studies*. Edward Elgar, UK.

$q = M(A_{i,j}^{R,S}, F_{i,j}^{R,S}, eu_i^R)$

hvor

$A_{i,j}^{R,S}$ *er leverancer fra erhverv i til erhverv j fra region R til region S*

$F_{i,j}^{R,S}$ *er leverancer fra erhverv i til endelig anvendelseskomponent j fra region R til region S*

eu_i^R *er eksport til udlandet fra erhverv i fra region R*

AIDA opererer med 12 regioner, 6 erhverv og 7 komponenter af endelig anvendelse. I AIDA er handlen mellem regioner opgjort for sektorer, dvs. input-outputmodellen etablerer en forbindelse mellem på den ene side produktionsværdier for regioner og erhverv og på den anden side råvareefterspørgsel ($A_{i,j}^{R,S}$) henholdsvis endelig anvendelse ($F_{i,j}^{R,S}$) for regioner og erhverv. Handlen mellem regioner antages at blive påvirket på samme måde som den internationale eksport, dvs. beregnet med de udenrigshandelselasticiteter, som på daværende tidspunkt blev anvendt i nationale modeller. Givet ændringer i interregional eksport er den interregionale handel estimeret med en gravitations- eller entropimaksimeringsmodel, hvor handelsstrømme estimeres som en funktion af transportomkostningerne. I modellen indgår – beregnet med gravitationsmodellen – den omfordeling af den interregionale eksport og det interregionale handelsmønster, som opstår, fordi de indenlandske transporter falder efter åbning af den faste Storebæltsforbindelse.

AIDA er i flere henseender mangelfuld, hvilket begrænser validiteten af de præsenterede resultater. For det første bør påvirkningen fra ændrede transportomkostninger til færdigvarepriserne integreres i AIDA. For det andet bør den Isard'ske interregionale input-output-mængdemodel erstattes af en model, som bygger på principperne i den generelle mængdemodel, hvor interregional handel modelleres i varer. Endelig bør flere effekter, som fx virkninger af nedlæggelse af færgetrafik og trafikkorridoreffekter, men også langsigtspåvirkninger af lager og logistik samt flyttebevægelser.

12. Den faste Femern Bælt-forbindelse[43]

De regionale konsekvenser af en fast Femern Bælt-forbindelse analyseredes i forskellige rapporter og artikler, især Cnotka m.fl. (1994), Madsen og Jensen-Butler (1999a og 2003) samt Jensen-Butler og Madsen (2000). Kendetegnende for den faste Femern Bælt-forbindelse er, at den er international, modsat den faste Storebæltsforbindelse, som primært har en indenlandsk betydning. Den faste Femern Bælt-forbindelse forbinder to metropoler og passerer et grænseområde mellem Danmark og Tyskland præget af lav økonomisk aktivitet og svag økonomisk udvikling. Den første analyse viser stort set balance mellem gevinst og tab af arbejdspladser, fordi konkurrenceevnegevinsterne ud fra et beskæftigelsesmæssigt synspunkt stort set blev opvejet af tab af arbejdspladser ved nedlæggelse af færgedrift. Særligt for Storstrøms Amt og Kreis Ostholstein (Cnotka m.fl. 1994; Jensen-Butler og Madsen 2000) er der tab af arbejdspladser, fordi færgetrafikken på daværende tidspunkt havde stor beskæftigelse. I senere opdaterede analyser (Madsen og Jensen-Butler 1999a) er tabene blevet reduceret, fordi den beskæftigelsesmæssige betydning af færgetrafik er faldet i takt med indførelse af ny

[43] Jensen-Butler, Chris og Bjarne Madsen (2000): An Eclectic Methodology for Assessment of the Regional Economic Effects of the Femern Belt Link Between Scandinavia and Germany. *Regional Studies*, Vol 33.8, pp. 751-768.

færgeteknologi. For hovedstadsregionen er der tale om en væsentlig gevinst, især fordi hovedstadsområdet kunne drage fordel af etablering af højhastighedstog til Hamburg og kontinentet.

Metodemæssigt adskiller Femern Bælt-analyserne, som ligeledes er en ex ante-analyse, sig fra Storebæltsanalyserne ved at inddrage flere effekter samt ved at anvende en simplere tilgang til analysen af konkurrenceevneeffekterne. For det første ses i analyserne på betydning af overgang fra færgedrift til fast forbindelse – og de økonomiske konsekvenser for afledt økonomisk aktivitet som for eksempel hotel- og trafikservice samt effekter for konkurrerende færgeruter. For det andet ses på de internationale konkurrenceevneeffekter for hele Europa, hvor Storebæltsanalysen alene fokuserede på påvirkningen af den relative konkurrence mellem danske amter.

Som konsekvens heraf anvendtes forskellige modelværktøjer:

- Trafikmodel for trafik mellem Skandinavien og kontinentet.
- Enregionsmodel for økonomisk aktivitet i Storstrøms Amt – EMIL-modellen.
- AIDA – interregional model for danske amter.
- Potentialemodel til belysninger af ændringer i konkurrenceevnen for forskellige regioner i Europa.

Dette sæt af modeller benyttedes til at beregne konsekvenser for produktion, indkomst og beskæftigelse regionalt såvel som lokalt af

- erstatning af færge med fast forbindelse (EMIL),
- omlægning af korridortrafikken fra de svenske Østersøruter og Jyllandskorridoren til Femern Bælt-korridoren (trafikmodel),
- øget aktivitet i overnatnings- og restauranterhvervene (trafikmodel henholdsvis EMIL),
- forbedret og forringet tilgængelighed for forskellige regioner i Skandinavien og på kontinentet (potentialemodel)

I analyserne sammenfattes tilgangen som eklektisk, fordi det af data- og modeltekniske årsager ikke var muligt at opstille en omfattende model for de nationale og internationale virkninger af en fast Femern Bælt-forbindelse mht. regional konkurrenceevne.

Metodemæssigt repræsenterer analysen en forbedring i og med, at flere effekter inddrages – fx effekter af nedlæggelse af færgedriften og korridoreffekter. Modelmæssigt er analysen status quo, da AIDA-modellen anvendes som referenceramme, hvor konsekvenser af ændringer i transportomkostninger ikke er integreret i den interregionale model, ligesom den interregionale input-output-mængdemodel er Isard-typen, hvilket indebærer teoretiske vanskeligheder.

Hverken Storebælts- eller Femern Bælt-forbindelserne er analyseret ved ex post-beregninger. I relation til Øresundsforbindelsen blev der gennemført udredninger af metoder til modelbaseret dekomponering af effekterne af trafikanlæg (Madsen 2000; Madsen og Jensen-Butler 2001). Det beskrives, hvorledes (interregionale generelle ligevægts-) modeller kan benyttes til såvel ex ante- som ex post-evaluering af den faste Øresundsforbindelse. Metodikken har fundet anvendelse i analyser af den regionale udvikling (Madsen og Jensen-Butler 2002; Jensen-Butler og Madsen 2005). Trods de faste forbindelsers store betydning for den økonomiske udvikling har der ikke været gennemført forskning i forbindelsernes betydning ex post (alle tre forbindelser) og ex ante (Øresundsforbindelsen).

13. Vejafgifter[44]

Et centralt emne i den seneste halve snes år har været virkningerne af vejafgifter. Et første studium i regionale konsekvenser af vejafgifter er konsekvenserne af at gøre det gratis at passere den faste Storebæltsforbindelse (Madsen m.fl. 2003; Madsen & Jensen-Butler 2004a), dvs. vejafgifter med modsat fortegn. I denne analyse reduceres priserne på varer og tjenester ca. 0,2%, hvilket påvirker prisen på eksport til udlandet. Stigende eksport til og faldende import fra udlandet fører til voksende efterspørgsel og produktion med en samlet stigning på knap 6000 beskæftigede. I analysen ses samtidig på virkningen af at finansiere udgifter til gratis passage over indkomstskatterne, som reducerer efterspørgsel og produktion og dermed beskæftigelsen med knap 2000, hvilket giver en nettoeffekt af gratis passage med skattefinansiering på ca. 4000 beskæftigede. Regionalt betyder gratis passage mest for hovedstadsregionen, Vestsjællands og Fyns Amter, mens Nordjylland får et relativt tab.

I et andet studie af de regionale konsekvenser af indførelse af vejafgifter for lastbiler (Madsen m.fl. 2003) påvirkes omkostninger til transport af varer og service. Dermed vokser priserne på eksport til udlandet i de fire scenarier mellem 0,2 og 0,6% – afhængig af, om afgiften kun indføres i udlandet eller også i Danmark. Faldende eksport mv. fører til tab af arbejdspladser mellem 1500 og 3000.

Fælles for de nye analyser er, at LINE anvendes. Hvor transporteffekterne med AIDA var eksogent fastsatte, indgår transportomkostningsændringerne i LINE's prismodel. I AIDA ændres eksporten til udlandet eller andre regioner eksogent pga. transportomkostningsreduktionen, hvilket påvirker priserne på regionernes eksport/import og dermed eksport og import til og fra udlandet og det regionale samhandelsmønster (modelleret i en gravitations- eller entropimaksimeringsmodel). I LINE indgår transportomkostningsændringerne i den samlede prisdannelsesproces. Som beskrevet i afsnit 5 om den generelle interregionale prismodel dannes de regionale og lokale omkostninger og priser i en kædeberegning, hvor omkostningsændringer overvæltes til næste led i produktionskæden og ender hos slutbrugeren (indenlandsk endelig anvendelse eller eksport til udlandet). Reduktion i transportomkostningerne ved gratis passage af den faste Storbæltsforbindelse eller øgede transportomkostninger ved vejafgifter for lastbiler eller for personer påvirker varepriserne i nedad- henholdsvis opadgående retning. Disse påvirkninger overvæltes i næste led i produktionskæden, som igen overvæltes i næste led osv. De samlede virkninger heraf er beregnet numerisk i LINE, men kan illustreres ved løsningen til den generelle interregionale prismodel (jf. præsentationen af den generelle interregionale prismodel i afsnit 5).

I ***afsnit 13*** (Larsen m.fl. 2007) bliver resultaterne af en analyse af de regionale virkninger af en vejafgift for personbiler præsenteret. I denne analyse indgår mængde- og prismodellen af LINE, dels i standardversionen, som beskrevet ovenfor, dels med tilføjelse af eksternaliteter. For det første er inddraget virkningen af "by-eksternaliteter", dvs. det forhold, at nærhed til bycentre alt andet lige øger indtjeningen pr. ansat. For det andet inddrages "pekuniære eksternaliteter", som bygger på, at lønnen er højere jo større afstand fra arbejdsstedet. Begge relationer for eksternaliteter er estimeret af Morten Larsen og indgår i Larsen m.fl. (2007) til beregning af de regionale konsekvenser af vejafgifter.

[44] Larsen, Morten Marott, Bjarne Madsen og Chris Jensen-Butler (2007) Modelling Transport in an Interregional General Equilibrium Model with Externalities I: *Regional Externalities*, Wim Heijman (ed.).

Af analysen fremgår, at transportomkostningerne i gennemsnit forventes at stige 5-10% – mest for regioner, som benytter bil, som foregår inden for eget byområde (intraregional transport) og mindst, hvis transporten foregår i yderområder uden for bymæssig bebyggelse. Disse fordelingsvirkninger afspejler, at vejafgiften er højest i byområder og lavest i land-områder, at vejafgiften vejer mest i områder med højt bilejerskab og mindst i byområder med korte transportafstande. Derfor tegnes et mønster, hvorefter bycentre i København og Århus betaler lave kørselsafgifter, mens trafik i forstadsområder, specielt i hovedstaden, betaler høje kørselsafgifter, mens transport i land- og udkantsområder betaler lave kørselsafgifter. I beregningen uden eksternaliteter fås relativt højere prisstigninger for produktion og eksport for regioner med høje kørselsafgifter og lavere for bycentre. Priserne for privat forbrug op-gjort efter bopæl påvirkes mest i områder, hvor shopping påføres relativt høje kørselsafgifter (fx forstadsområder til København), og mindre i områder, hvor der er lavere kørselsafgifter. Heraf følger, at der alt i alt mistes ca. 8.400 arbejdspladser, hvis der ikke tages hensyn til eksternaliteter.

Hvis der herudover forudsættes, at øgede transportomkostninger resulterer i færre by-ekster-naliteter og større lønovervæltning, forøges tabet af arbejdspladser til ca. 12.600. Det fremgår af modelberegningerne, at det især er virkningerne af tilpasning af lønningerne ved højere transportomkostning, som fører til lavere økonomisk aktivitet (ca. 2.900 arbejdspladser) mod effekterne af mindskede by-eksternaliteter (ca. 1.300 arbejdspladser).

14. Telearbejde[45]

En videre anvendelse af LINE inden for transport er sammenhængen mellem regional ud-vikling og telearbejde. Telearbejde er her defineret som hjemmearbejde, der benytter informations- og kommunikationsteknologi (ICT). I ***afsnit 14*** modelleres den regionale betydning af telearbejde, hvilket modeltekniske beregnes som tabet af arbejdspladser ved at fjerne telearbejde – med modsat fortegn.

De direkte regionale effekter opdeles i 1) de direkte efterspørgselseffekter, som stammer fra den direkte reduktion i pendlingsomkostningerne ved telearbejde, 2) arbejdsmarkedsudvidel-seseffekten, som hidrører fra den øgede mulighed for, at telearbejde udvider det geografiske opland for arbejdskraften, og 3) produktivitetseffekten af telearbejde, som består i, at produk-tiviteten ved at arbejde hjemme potentielt er højere end ved at arbejde på arbejdspladsen.

Telearbejde kan betragtes som en substitut for pendling, som kan gennemføres med forskellig transportmåde. Hver transportmåde repræsenterer forskellig nytte for forskellige trafikanter. Vigtigst i denne sammenhæng er, at telearbejde repræsenterer en tidsbesparelse, som på for-skellig måde kan anvendes til at opnå nytte af anden anvendelse. Hertil kommer, at tele-arbejde normalt også fører til reduktion i transportomkostninger. Hole m.fl. (2004a) estimerer andelen af telearbejdere, som er højest blandt højtuddannede, højindkomstgrupper, andel af personer uden ledelsesmæssige funktioner mv. Denne andel benyttes som udgangspunkt for bestemmelsen af antal fuldtidstelearbejdere (knap 20.000) og deres regionale fordeling. Da uddannelses- og indkomstniveau er højest i København følger, at andelen af telearbejdere er

[45] Madsen, Bjarne; Arne Risa Hole, Chris Jensen-Butler, Morten Marott Larsen og Lasse Møller-Jensen (2007): Teleworking and transport: Modelling the regional impacts in an interregional General Equilibrium Model with externalities.

højest i København. Med udgangspunkt heri estimeres reduktionen i pendlingsomkostninger, hvoraf afledes en reduktion i disponibel indkomst på knap 200 mio.kr.

Arbejdsmarkedsudvidelseseffekten – eller de positive eksternaliteter af reducerede transportomkostninger – estimeres med samme teknik som i Larsen m.fl. (2007). Øget mulighed for telearbejde reducerer de effektive transportafstande, hvilket mindsker den reelle løn, hvilket igen sænker eksportprisen, øger eksporten og dermed produktion, indkomst og beskæftigelse.

Med udgangspunkt i Hole m.fl. (2004b), som har estimeret en U-formet produktivitetskurve for omfanget af telearbejde, kan produktivitetseffekten af "intet telearbejde" estimeres. Produktivitetskurven viser, at produktivitetsgevinsten ved en dags hjemmearbejde er høj og aftager, indtil den maksimale gevinst ved telearbejde opnås. Herefter reduceres gevinsten ved telearbejde ved yderligere hjemmearbejdsdage. I den U-formede kurve tages hensyn til, at der er fordele ved "ro og fred" ved de første hjemmearbejdsdage, mens tab ved manglende kollegiale kontakter fra et bestemt omfang af telearbejde reducerer værdien af yderligere telearbejde. Øget produktivitet ved telearbejde reducerer produktionsomkostningerne pr. produceret enhed, hvilket sænker priserne, herunder eksportpriserne, hvilket øger eksporten og dermed produktion, indkomst og beskæftigelse.

Samlet beregnes beskæftigelsesvirkningen til ca. 250 – højest i hovedstaden og lavest i udkantsområder. Det afspejler for det første, at andelen af telearbejde generelt er meget lav. For det andet afspejler det, at den største andel af telearbejdere findes i hovedstaden, hvor også uddannelses- og indkomstniveau er højest.

15. Turisme og gratis transport over den faste Storebæltsforbindelse[46]

Sidste eksempel på en anvendelse af LINE til analyser af regionale konsekvenser af transportregulering er konsekvenserne af at gøre det gratis at passere den faste Storebæltsforbindelse for turismen. I sig selv er de regionale konsekvenser begrænsede: Gevinsten målt i arbejdspladser beregnes til omkring 200. Men omlægning i valg af turistdestination kan være betydelig, og kan derfor potentielt have betydelige konsekvenser for trafik og miljøbelastning. Da udgifter til passage af den faste Storebæltsforbindelse udgør en ikke ubetydelig del af transportudgifterne til en turistdestination i Danmark og dermed for prisen for et givet turistprodukt – fx for familier bosat i København, som tager på sommerhusferie i Vestdanmark – kan en omvendt roadpricing, som fjerner brugerbetaling, gøre det attraktivt at rejse længere, hvilket påvirker trafik og miljøbelastning ved turistbaseret trafik. Og dette aspekt er væsentligt i diskussionen omkring reduktion i trafik og dermed i miljøbelastning fra transportsektoren.

Metodisk er præsentationen af LINE særlig, idet den beskriver opbygning af delmodellen for så vidt angår det private forbrug, som er opdelt i turistudgifter og lokalt privat forbrug. Turistudgifter er igen opdelt i turistudgifter i forbindelse med traditionel overnatningsturisme, som igen er underopdelt på danske og udenlandske turisme, og endagsturisme, som ligeledes er underopdelt i dansk og udenlandsk endagsturisme. For de forskellige typer turisme og lokalt privatforbrug indgår bestemmelse af turistdestination (varemarkedssted) og bopæl, som enten kan være bopælskommunen eller turistens nationalitet. I LINE modelleres turisme efter-

[46] Madsen, Bjarne; Chris Jensen-Butler og Jie Zhang (2003): The regional impacts on tourism of traffic regulation. The case of Denmark. *Urban & Regional Development Studies*, May 2003.

spørgslen for udenlandsk turisme ved at gange døgnforbrug med antal overnatninger/endagsturister, mens turistudgifterne for danske turister bestemmes af den disponible indkomst og det samlede privatforbrug. I LINE modelleres ligeledes prisen for de forskellige turistprodukter, som afhænger af transportomkostningerne til og fra destinationen. I analysen påvirkes prisen på de forskellige turistprodukter dermed af billiggørelsen af transporten ved at gøre det gratis at passere den faste Storebæltsforbindelse, for så vidt den faste Storebæltsforbindelse er en nødvendig transportvej for turisten. Ved at antage at, antallet af overnatninger påvirkes af prisen på turistproduktet, modelleres konsekvenserne for valg af turistdestination (jf. Jensen 1998). Ved at anvende LINE findes desuden de afledte konsekvenser af ændringen i turistefterspørgslen.

16. Afslutning

Opstilling af den generelle interregionale model er den centrale del af afhandlingen og hjælper til at forstå den regionale og lokale økonomi. Hvor regionale analyser alene beskriver den økonomiske aktivitet inden for regionen i sin helhed og den økonomiske interaktion mellem regionerne, udvider den lokale model analysen af økonomisk aktivitet på lokalområder inden for en region, ligesom modellen kvalificerer forståelsen af det økonomiske samspil mellem lokalområder – og mellem regioner i det omfang, der er interaktion på tværs af regionsgrænserne.

Den generelle interregionale model formuleres teoretisk, og dens analytiske løsning præsenteres. Den generelle interregionale model benytter det såkaldte 2 x 2 x 2-princip, som er en central del af afhandlingen. 2 x 2 x 2-princippet bygger på, at den lokale økonomi har to typer agenter, producenter og institutioner, har to markeder, faktor- og varemarkedet, og for alle udbuds- og efterspørgselsflow har et geografisk start- og slutpunkt. Som konsekvens opereres med fire geografiske begreber – arbejdssted, faktormarkedssted, bopæl og varemarkedssted – og fire social accounting-begreber – erhverv, typer af produktionsfaktorer, typer institutioner og varer.

Modellen opstilles i ændringer, således at den generelle interregionale model kan benyttes til analyser af virkninger af ændringer i den lokale og regionale økonomi som fx regionale og lokale konsekvenser af demografiske ændringer.

LINE, som er en anvendt lokaløkonomisk model, og som bygger på principperne i den generelle interregionale model, præsenteres. Et antal anvendelser, som rækker fra fremskrivninger til konsekvensberegninger, hvoraf nogle er ex ante- og andre er ex post-beregninger, præsenteres. Principperne bag opbygning af et lokalt nationalregnskab (SAM-K), som bl.a. benyttes i LINE, præsenteres ligesom analyser af gode arbejdsprincipper fx med hensyn til aggregeringsniveau i SAM-K, gennemgås.

Set i dette lys kunne en afslutning naturligt berøre fremtiden. Her springer det klart i øjnene, at de empiriske muligheder for mikrobaserede analyser er kraftigt voksende. Datamæssigt er allerede en væsentlig del af SAM-K mikrobaseret (data vedr. indkomst og beskæftigelse for personer). Næste skridt, som inkluderer mikrodata vedr. tilgang og anvendelse af varer, ligger lige for. Som naturlig konsekvens er, at det lokale nationalregnskab – baseret på 2 x 2 x 2-princippet – i sin helhed opstilles på grundlag af mikrodata, hvorefter afstemningsprocedurer på mikro-, meso- og makroniveau sikrer overholdelsen af basale bogholderimæssige identiteter.

Modelmæssigt forekommer mikrosimuleringsmodeller som næste skridt i en forbedring af den generelle interregionale model: Mikrosimulering af beslutninger på mikroniveau (producenter og institutioner) efterfulgt af modellering i den generelle interregionale mængde- og prismodel til sikring af ligevægtskrav vedr. mikro-, meso- og makroniveau, forekommer som en naturlig og nødvendig udvikling på det regional- og lokaløkonomiske forskningsfelt. I den forbindelse har afhandlingens forfatter i en projektansøgning til Forskningsrådet for Erhverv og Samfund formuleret ”den generelle regionale mikrosimuleringsmodel”. Udviklingen af denne model er imidlertid kun i sin vorden og er derfor ikke inddraget i denne afhandling.

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Main Section A:

Regional and Local Development in Denmark

Section 2:

Regional Development Trends in Denmark

Bjarne Madsen & Anne Kaag Andersen

Section 2

Regional Development Trends in Denmark

Bjarne Madsen and Anne Kaag Andersen

1. Regional development objectives

The primary purpose of this article is to examine regional development in the years ahead. First, the authors delimit and define the term "regional development" and how it can be measured. Based on this, the status of regional development from 1980 to the present is described in brief. Next, the authors present the results of a baseline projection of regional development up to 2010 and analyses of the regional effects of different market-specific development trends and various possible political initiatives/decisions. The consequences of the baseline projection and scenario analyses are assessed in relation to regional development objectives.

1.1. "Regional development" defined

Denmark's regional development has many stakeholders. In its regional policy statement (2002), for example, the Government stated that "the Government aims to ensure that the people of Denmark have good, equal living conditions, regardless of where one chooses to live. It is the Government's wish that all areas of Denmark are attractive areas for development and residence in order to achieve a geographical dispersion of the population and economic activity. Finally, the Government will endeavour to ensure that the regional development in the long term reduces inequality in terms of service, employment and financial conditions in the regions of Denmark."[1] The statement presents the Government's deliberations regarding various initiatives that could improve the regional balance.

The quotation from the Ministry of the Interior and Health gives a commendably clear, though perhaps not very operational, definition of the term "regional development". The first section relating to good and equal living conditions expresses convergence/divergence, i.e. the point of view of what is regarded as acceptable differences in per capita income across the country. The second section deals with the issue of concentration/deconcentration as regards jobs and population, i.e. the smallest or largest acceptable number of inhabitants, jobs, etc. The third relates to concentration/deconcentration as regards service, employment and economic conditions within the regions – again a question of minimum and maximum limits for these activities.

1.2. Reasons for the desire for convergence/divergence or concentration/deconcentration

Different premises are stated for the regional policy objectives – the proposed spread of economic activity (concentration/deconcentration) and the acceptable income gap (convergence/divergence). The desire for convergence is based on a distribution-policy aim to reduce regional differences in living conditions. Conversely, the desire to increase the income gap (divergence) is justified by the need for incentives to increase production in areas with high productivity, at the expense of production in areas where productivity is lower.

Different reasons are given for the desired concentration or deconcentration. A concentration of economic activity in large urban areas or in areas with specialised business activity is based on the gains brought about by concentrating production – e.g. by increasing productivity through econo-

[1] Similar considerations – though not quite this precise – are found in other Government documents, e.g. the Danish Ministry of the Environment's draft of a national development plan review.

mies of scale, through access to larger labour markets, etc., and through positive effects on productivity resulting from contact with similar or different types of enterprises. A desire for concentration may also be justified by the aim of maintaining a national culture and achieving that aim by strengthening the most sustainable aspects of that culture. Conversely, a desire for deconcentration may be justified by the aim of preserving a culturally significant local community (e.g. a rural area) or the desire to maintain the population level in outlying areas to counteract bottlenecking in urban centres.

1.3. Measuring regional development

There are a number of different operational targets that can be set for regional development. They reflect different functions of economic activity and can have (widely) varying results.

First of all, a number of targets for regional economic activity rely on the region's or local area's function as a place of production, place of residence or place of demand (marketplace). The gross domestic product at factor cost is an example of a target that applies to the place of production, while the disposable income refers to the households residing within a given region. The demand itself – e.g. private consumption, investment, etc. – is usually grouped with the place of demand.

Similarly, economic activity is also grouped with a specific factor of the regional economy – e.g. the producers (GDP at factor cost) or the institutions (the households). Finally, different targets for economic activity are selected – e.g. the player's primary income or disposable income. As will be shown below, it is possible to draw different conclusions depending on whether the focus is on the primary income, the tax base or the disposable income.

The choice of development targets is relevant when choosing which control instruments to use (business development, housing policy, etc.). In addition, it is possible to draw widely different conclusions depending on the choice of development targets. Accordingly, the definition of regional development selected is crucial.

This article illustrates regional development in terms of primary income, the tax base and disposable income. In doing so, regional development (concentration/deconcentration and convergence/divergence, respectively) is analysed from the perspective of place of residence (as distinct from place of work or demand) and from the perspective of households (as distinct from perspectives of production or demand).

2. Results so far

A number of analyses of regional development have already been carried out: some have focused on concentration/deconcentration, (e.g. Madsen et al. 1992; Groes 1997; Expert Committee (1998); Danish Ministry of the Interior and Health 1997; Norstrand et al. 2001; Madsen and Jensen-Butler 2002; Danish Government 2002), while others have focused on convergence/divergence (e.g. Dilling et al. 1994; Madsen and Rich 1994; Dilling and Smidt 1997; Groes 1997; Heinesen and Groes 1997; Madsen and Caspersen 1998; Sørensen 1998; Danish Government 2002). The main results and trends are assessed below.

2.1. Concentration – deconcentration

Population trends from 1980 to 2000 show an average yearly growth of 0.22% for Denmark as a whole. The population of Greater Copenhagen more or less followed this same growth trend, but this also encompasses zero growth (in Greater Copenhagen, i.e. in the Municipalities of Copenhagen and Frederiksberg and Copenhagen County) and substantial growth (in surrounding municipalities and the rest of Zealand). The population of Lolland, Falster and Bornholm sharply declined – both absolutely and in comparative terms. The population of Jutland increased, particularly in Central and East Jutland, while growth was relatively less in South, West and North Jutland. The population of agricultural municipalities, outlying municipalities and municipalities facing structural difficulties all declined comparatively. The population of rural municipalities remained unchanged, while the population of large urban areas increased.

Table 1. Average annual growth in population and income in the period 1980-2000 for selected regions and areas (concentration/deconcentration)

	Disposable income			Primary income			Population		
	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000
Municip. of Copenhagen & Fr.berg and Copenhagen County	5.32	3.68	4.66	6.29	4.27	5.48	-0.35	0.51	-0.01
Frederiksborg & Roskilde	7.11	3.83	5.78	7.76	4.14	6.29	0.52	0.73	0.60
Rest of Zealand	6.77	3.74	5.55	7.39	4.14	6.08	0.23	0.43	0.31
Lolland-Falster	6.04	3.13	4.86	6.09	2.96	4.82	-0.42	-0.12	-0.30
Bornholm	6.23	3.13	4.98	6.86	2.33	5.02	-0.41	-0.31	-0.37
Fyn	6.83	3.30	5.40	7.57	3.70	6.00	0.21	0.18	0.20
Sønderjyllands County	6.94	3.19	5.43	7.14	3.65	5.73	0.01	0.10	0.05
Ribe County	7.45	3.31	5.77	8.01	3.60	6.22	0.28	0.21	0.25
Ringkøbing County	7.09	3.46	5.62	7.67	3.96	6.17	0.06	0.13	0.09
Århus, Vejle etc.	7.17	3.92	5.86	7.89	4.36	6.47	0.35	0.58	0.44
Nordjyllands County	6.90	3.47	5.51	7.44	4.03	6.06	0.08	0.20	0.13
Whole of Denmark	6.56	3.63	5.37	7.27	4.08	5.98	0.09	0.40	0.22
Metropolitan area	5.87	3.73	5.01	6.79	4.22	5.76	-0.07	0.58	0.19
< 5,000	6.45	3.08	5.09	6.95	3.30	5.48	-0.53	-0.20	-0.40
5-10,000	7.02	3.59	5.64	7.48	4.10	6.11	-0.03	0.20	0.06
10-15,000	7.22	3.59	5.76	7.74	4.07	6.26	0.12	0.34	0.21
15-30,000	6.97	3.48	5.56	7.49	3.83	6.01	0.07	0.22	0.13
30-50,000	6.83	3.60	5.53	7.38	3.93	5.99	0.29	0.42	0.34
50-75,000	8.87	3.83	5.65	7.81	4.24	6.37	0.23	0.45	0.32
>75,000	6.92	3.51	5.54	7.69	3.91	6.16	0.53	0.41	0.48
Whole of Denmark	6.56	3.63	5.37	7.27	4.08	5.98	0.09	0.40	0.22
Rural municipalities	7.04	3.60	5.65	7.55	4.18	6.19	-0.08	0.23	0.05
Agricultural municipality	7.01	3.52	5.60	7.33	4.10	6.03	-0.17	0.09	-0.07
Outlying municipality	6.61	3.22	5.24	7.01	3.39	5.55	-0.34	-0.12	-0.25
Vulnerable I	6.23	2.96	4.91	6.67	2.82	5.11	-0.53	-0.32	-0.45
Vulnerable II	6.40	3.15	5.09	6.75	3.19	5.31	-0.41	-0.15	-0.30

The same trend applies to income: Greater Copenhagen has more or less the same percentage of the income as in 1980, but the activities have shifted from the Municipality of Copenhagen to the surrounding municipalities. There was a comparative increase in the population of Central and East Jutland, while the outlying municipalities, municipalities facing structural difficulties and sparsely populated municipalities declined comparatively. Bornholm, Lolland and Falster declined comparatively, but the trends in Funen and the rest of Jutland followed the national average.

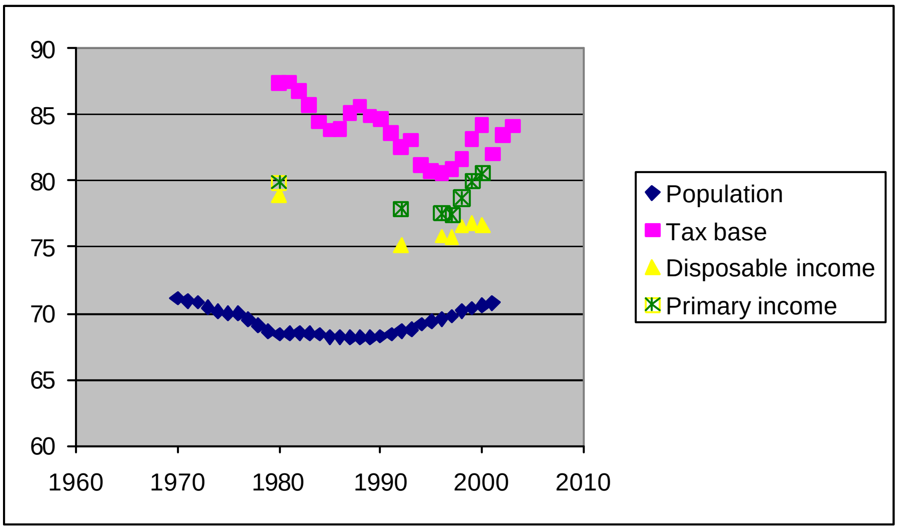
Overall, there was an apparent trend towards concentration as regards both population and income.

Subsidiary periods: structural shift?

As Table 1 shows, the growth pattern changed during the period, even if it is difficult to determine the exact point of deviation based on the figures available: before 1992, population and income were growing faster in Central and West Jutland than in Greater Copenhagen, which showed weaker growth. From 1992, growth in Greater Copenhagen was strikingly sharper than the national average, while total growth in Central and West Jutland was lower, but still equal to or slightly above the national average.

One target of overall concentration is population density or income density. If this density is the same in all labour catchment areas, this indicates a deconcentrated pattern of localisation. In this case, the density spread (i.e. the variation coefficient) is nil. On the other hand, if economic activity is concentrated in a few areas, the density is different and the spread (or the variation coefficient) is high and indicates concentration. Figure 1 shows the variation coefficient calculated in terms of commuter catchment areas for all levels of income (for 1980–2002) and for inhabitants (for 1970–2000). The same degree of concentration existed in 1970 as it does today.

Figure 1. Concentration trend in population and levels of income.[1] Variation coefficient[2] computed in terms of commuter catchment areas for inhabitant per km² and level of income per km² (concentration/deconcentration)



Source: The Institute of Governmental Research's interregional Social Accounting Matrices (SAM-K), cf. Madsen et al. (2001a).

1) It should be noted that the tax-base data in 2002 and 2003 are taken from the respective budgets and include possible corrections to compensate for the local governments' choice of state-guaranteed tax base.

2) The variation coefficient is calculated as the spread divided by the average. Unlike the spread, the variation coefficient depends on the absolute magnitude of the basic figures. For this reason, it is well suited for comparison over time.

The figure clearly indicates when the trend shift occurred and shows that the shift did not occur at the same time for the different variables included in the analysis. The figure shows that deconcentration occurred in the period's first segment, while concentration occurred in the second. The population shift does not occur until the late 1980s, when the trend shifts from deconcentration to concentration. The income changeover does not occur until the mid 1990s. The concentration process is striking in terms of both population and level of income. Based on the figures available for the 2002 tax base, the concentration trend appears to continue.

The concentration target in Figure 1 was computed using commuter catchment areas as a geographic unit. Deconcentration aptly describes the trend that occurred within the commuter catchment areas. For instance, the trends within the two large areas – Greater Copenhagen and Århus-Vejle – have followed the same pattern: the population and employment ratio of outlying municipalities within Greater Copenhagen has grown, concurrent with a relatively lower growth rate in the municipalities of Copenhagen and Frederiksberg and, to some extent, Copenhagen County. Similarly, growth in Central and West Jutland was concentrated around suburban areas and municipalities near large urban areas, particularly Århus and Vejle.

2.2. Convergence – divergence

As shown above, income trends have largely followed population trends, though with greater fluctuations. In other words, in areas with a declining population trend, the average incomes generally grow faster than the national average, and the opposite is true in areas whose growth is below the national average. Other factors being equal, this is an example of convergence.

Table 2. Development in the average primary income and disposable income 1980-2000 (convergence/divergence)

	Disposable income			Primary income		
	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000
Municipality of Copenhagen & Fr.berg and Copenhagen County	5.68	3.15	4.66	6.66	3.74	5.48
Frederiksborg & Roskilde	6.55	3.08	5.15	7.20	3.39	5.66
Rest of Zealand	6.53	3.30	5.22	7.14	3.70	5.75
Lolland-Falster	6.49	3.25	5.18	6.54	3.08	5.14
Bornholm	6.67	3.45	5.37	7.29	2.65	5.41
Fyn	6.60	3.11	5.19	7.34	3.51	5.79
Sønderjyllands County	6.93	3.09	5.38	7.13	3.55	5.68
Ribe County	7.15	3.09	5.51	7.71	3.38	5.96
Ringkøbing County	7.02	3.32	5.52	7.60	3.83	6.08
Århus, Vejle etc.	6.80	3.31	5.39	7.52	3.75	6.00
Nordjyllands County	6.81	3.26	5.38	7.36	3.82	5.93
Whole of Denmark	6.46	3.21	5.15	7.18	3.66	5.76
Metropolitan area	5.94	3.13	4.81	6.87	3.62	5.56
< 5,000	7.02	3.28	5.51	7.52	3.51	5.90
5-10,000	7.06	3.39	5.57	7.51	3.90	6.05
10-15,000	7.09	3.24	5.54	7.61	3.72	6.04
15-30,000	6.89	3.25	5.42	7.41	3.61	5.88
30-50,000	6.52	3.17	5.17	7.08	3.50	5.63
50-75,000	6.66	3.36	5.31	7.57	3.77	6.03
>75,000	6.35	3.09	5.03	7.12	3.48	5.65
Whole of Denmark	6.46	3.21	5.15	7.18	3.66	5.76
Rural municipalities	7.12	3.36	5.60	7.63	3.94	6.14
Agricultural municipalities	7.19	3.42	5.67	7.51	4.00	6.10
Outlying municipalities	6.97	3.35	5.51	7.37	3.52	5.81
Vulnerable I	6.79	3.29	5.38	7.23	3.15	5.58
Vulnerable II	6.83	3.31	5.41	7.19	3.34	5.63

Throughout the period, the annual growth of the average primary income and disposable income was 5.76% and 5.15%, respectively. The annual growth of the average primary income was 0.3-0.4% greater in Central and West Jutland, whereas the annual growth in Greater Copenhagen was

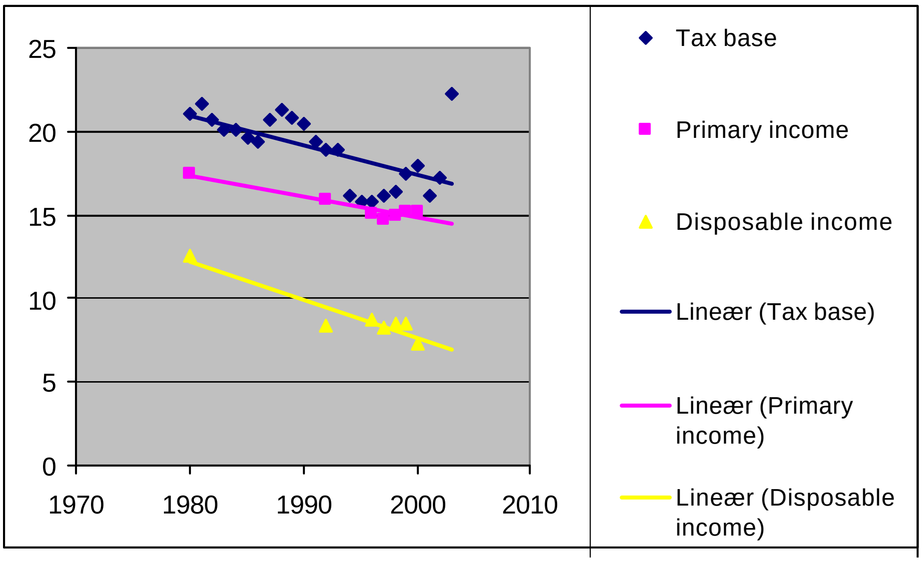
0.3% less. For large urban areas, the annual growth was less than 0.3%, while the growth for rural municipalities, agricultural municipalities, outlying municipalities and municipalities facing structural difficulties was the same as or slightly below the average as regards primary income, while it was the same as or above the average as regards disposable income.

Disposable income trends, however, generally follow primary income trends, yet are significantly weaker. This is because the income increase is taxed and employment growth reduces the transfer payments.

This development pattern has generally led to convergence in the period. At the start of the period, Greater Copenhagen, which is slightly above average, experienced lower growth in average income, thus contributing to convergence. Similarly, many of the municipalities in Central and West Jutland were below average at the start of the period. Growing economic activity caused the average income to rise and also helped to even out the level of income. Conversely, weak growth in primary income in outlying municipalities and municipalities facing structural difficulties contributed to unchanged or slightly increasing differences, without, however, changing the general convergence trend. They did better in terms of disposable income.

Subsidiary periods: structural shift?
As in the issue of concentration/deconcentration it makes sense to study whether a change also occurs from around 1992 onward and whether new trends have arisen in recent years. To accurately assess this issue, the trend is depicted in the figure below as the diversification of the average incomes.

Figure 2. Variation coefficients computed at municipal level for per capita incomes[1] (convergence/ divergence)



Source: The Institute of Governmental Research's interregional Social Accounting Matrices (SAM-K), cf. Madsen et al. (2001a).

1) It should be noted that the tax-base data in 2002 and 2003 are taken from the respective budgets and include possible corrections to compensate for the local governments' choice of state-guaranteed tax base.

The figure shows that the differences in per capita disposable income have steadily declined (convergence) throughout the period. As regards per capita primary income, a change apparently occurred around 1995 leading to a greater spread – or divergence – up to 2000. The same trend occurred with the tax base, where convergence was replaced by divergence in the mid 1990s. The latter seems to indicate that the income tax system is largely responsible for the fact that the disposable income does not manifest the same divergence indications as the primary income.

3. Future trends

Most analyses of future regional development deal with concentration and deconcentration, but do not consider the aspect of convergence/divergence. The hitherto most comprehensive assessment of regional development in the years ahead was made within the framework of the research programme "Jordbruget i landdistrikternes økonomi og udvikling" (Agriculture in the economy and development of rural areas) funded by what is now the Directorate for Food, Fisheries and Agri Business under the Ministry of Food, Agriculture and Fisheries.

A combined modelling system was developed under the research programme comprising existing models for international economy (the GTAP model) and the Danish economy (AAGE) and a new model for regional and local economy (LINE) and agriculture (ESMERALDA). The modelling system is used for projecting regional development – setting up a baseline process. The modelling system is also used in a number of sensitivity analyses depicting how the regional development process will change if different probable deviations take place/are realised.

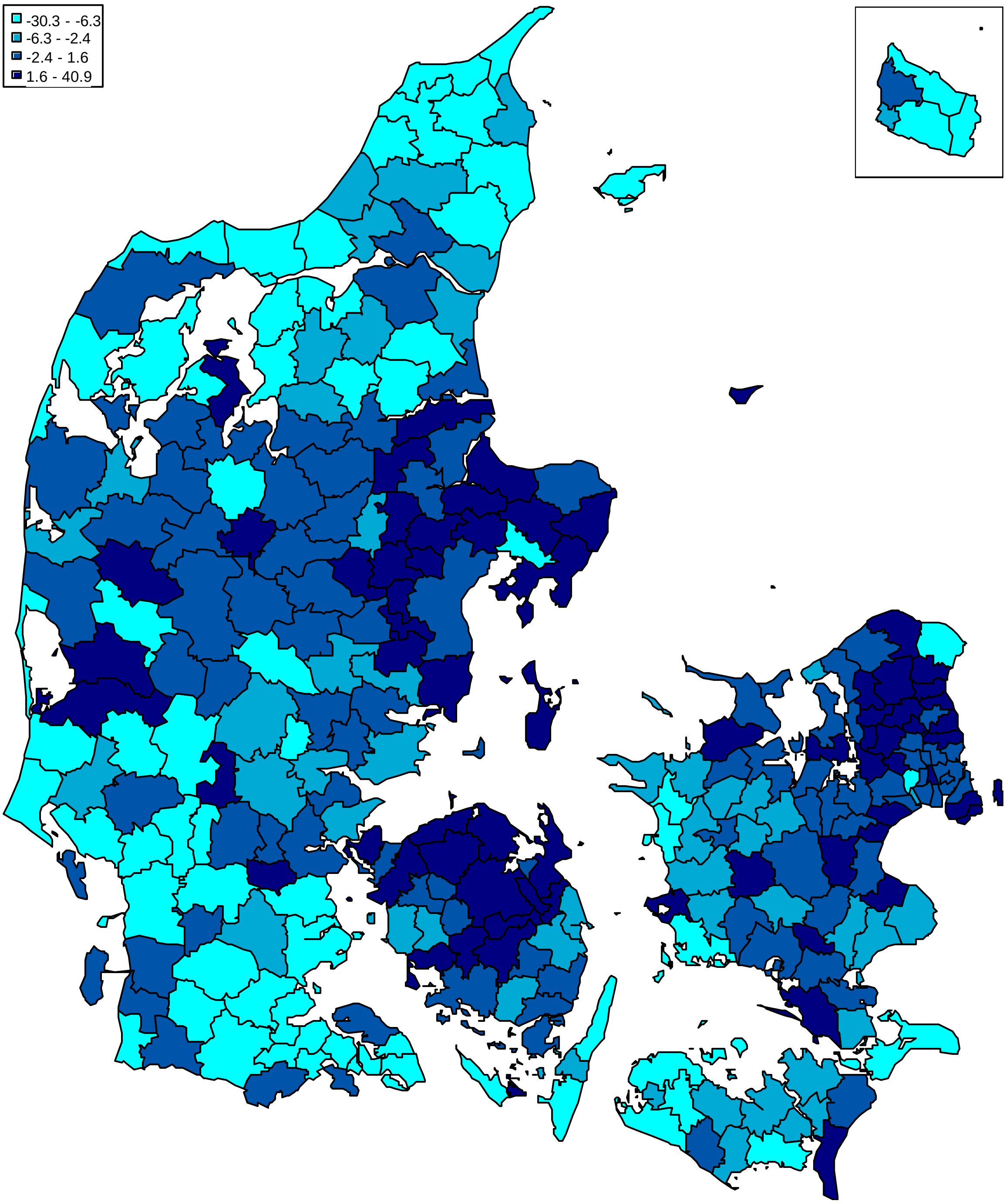
3.1. Baseline scenario

In their analyses of the baseline scenario, Hasler et al. (2002) consider income trends only, i.e. without analysing the implications for the average incomes. Accordingly, the model calculations can only be used to determine whether concentration/deconcentration will occur, whilst the aspect of convergence/divergence can only be estimated. This is also because changes in population are not defined in the model, but taken from Statistics Denmark's population projections.

Concentration or deconcentration

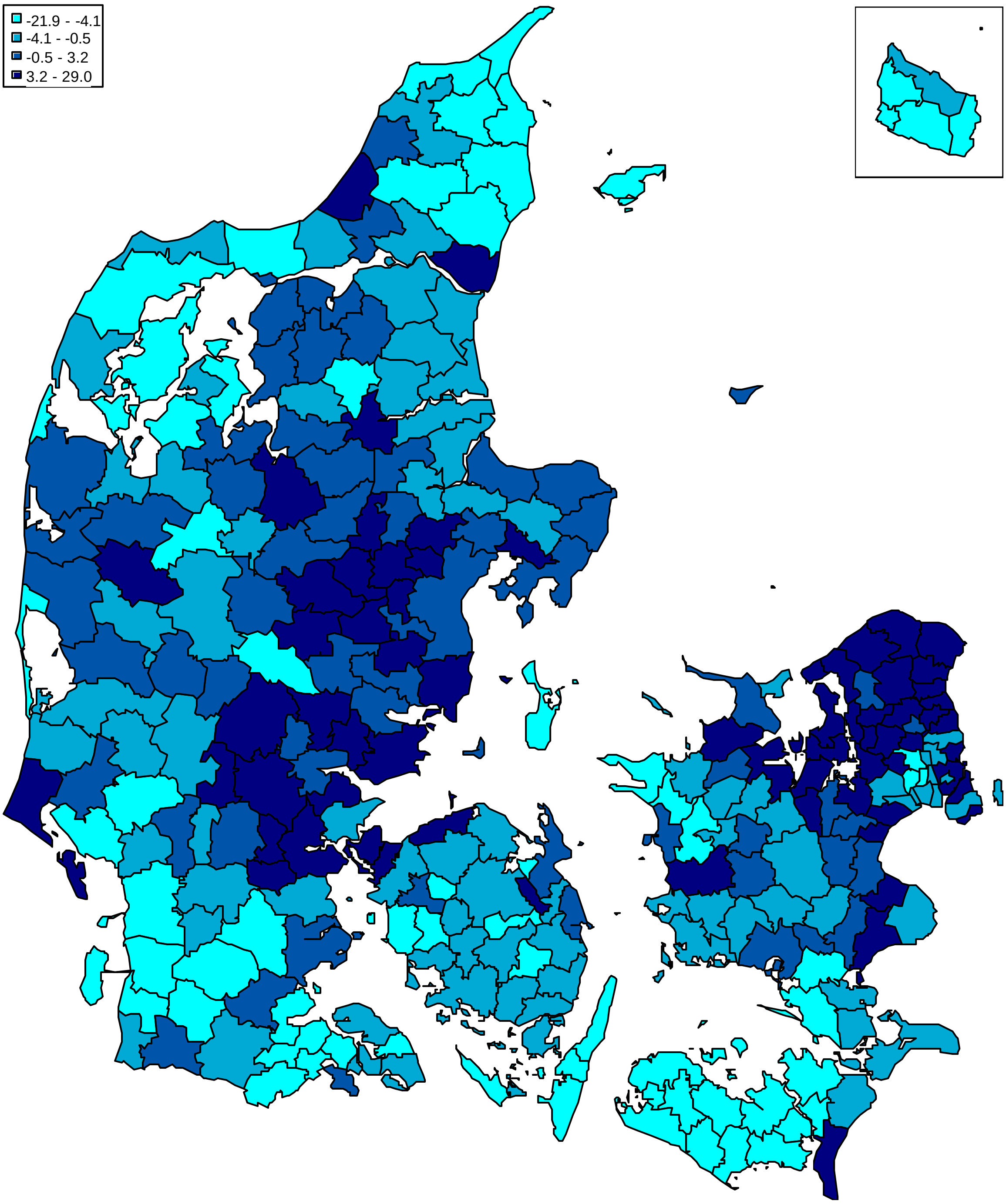
As regards the baseline, there is every indication that the growth will be weaker in rural areas, while Greater Copenhagen and the largest urban areas will begin to prosper. This trend is illustrated by charts showing GDP-at-factor-cost trends according to place of production (Figure 3), the disposable income assessed in terms of the place of residence (Figure 4) and population (Figure 5):

Figure 3. Relative change in the GDP at factor cost from 1995 to 2010, baseline scenario. Percentage deviation from the national average



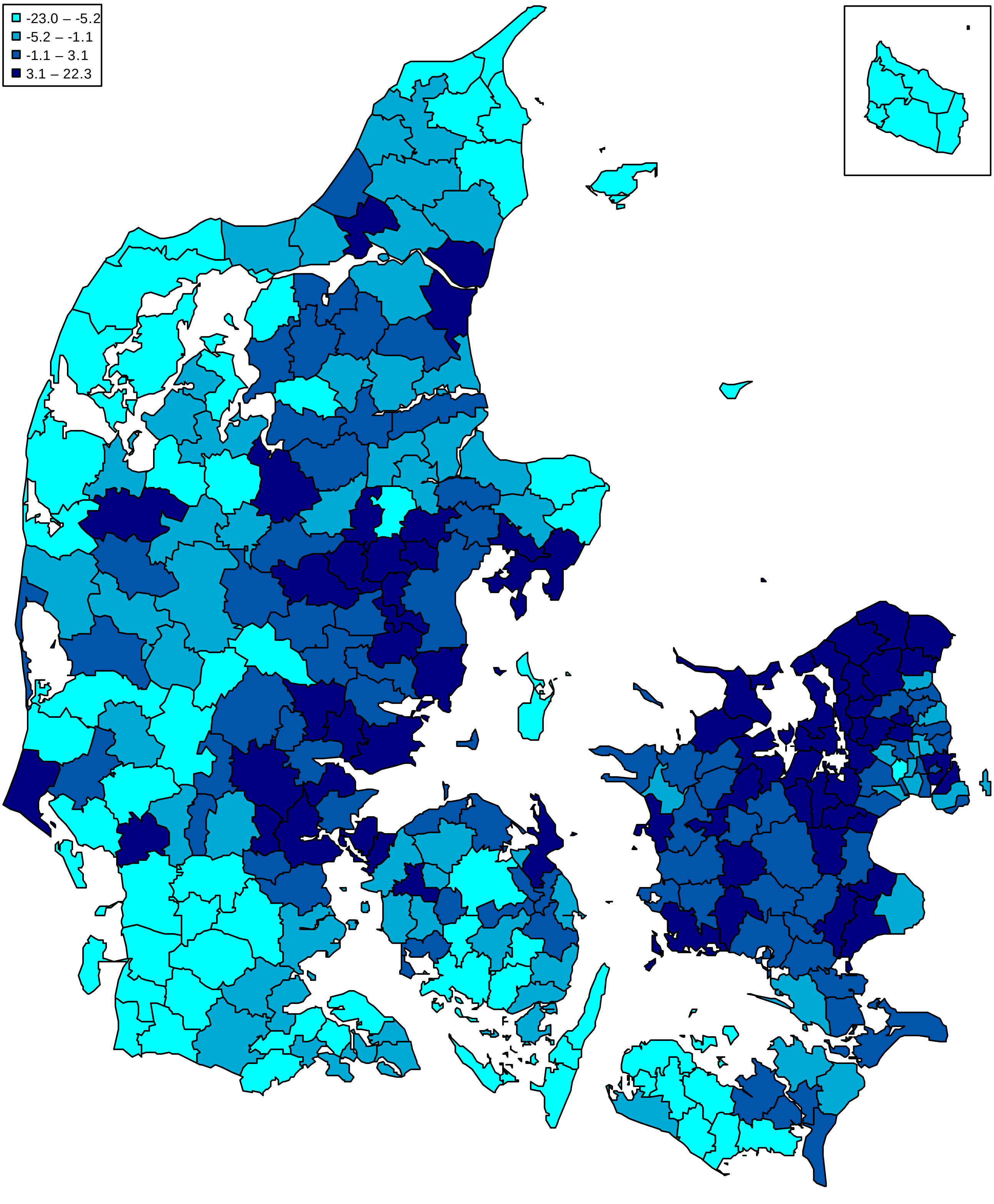
Source: Computed using the LINE model (Madsen et al. 2001b; Hasler et al. 2002).

Figure 4. Relative change in disposable income from 1995 to 2010, baseline scenario. Percentage deviation from the national average



Source: Computed using LINE (Madsen et al. 2001b; Hasler et al. 2002).

Figure 5. Relative change in population from 1995 to 2010, baseline scenario. Percentage deviation from the national average



Source: Statistics Denmark's population figures and projections.

The projection assumes that demand develops in accordance with known trends where growth is concentrated around growth in business service, etc., and advanced industrial products, whereas the demand for food and industrial products with a low degree of processing generally shows insignificant growth. At the same time, the projection assumes that productivity trends will follow known trends in the business sectors. The population trend, which is particularly important to developments within local businesses, follows Statistics Denmark's population projections.

Overall, there is every indication that the concentration trend will continue, even if no consequential analyses of the income spread per km² have been carried out, cf. Figure 1.

Convergence or divergence
As regards population trends, the population shifts obviously "follow" the growth of production and income to a great extent, although at a subdued level (Figure 5): i.e. a growing number are getting a slice of a larger cake. As this happens, the areas of growth will experience – concurrent with immigration to the areas – a relatively lower rise in the average income (but still above average) while areas of recession will see a sharp rise in the average income (but still below average) concurrent with emigration from the areas. This is true for both the average GDP at factor cost and the average disposable income.

There are many indications that divergence will become a trend, because Greater Copenhagen, with income above the national average, will prosper more than the rural municipalities, etc., which in turn will see declining incomes and below-average incomes.

3.2. Alternative scenarios
As part of the research programme, a number of subsidiary analyses were also performed to determine what would happen if baseline factors were to evolve differently than expected. These changes originate from *market-related adjustments* and changes resulting from *policy-based control*. The analysis results are summarised in the table below:

Table 3. Consequences for income in terms of baseline and market-specific scenarios and policy-control scenarios

	Gr. Cph. and large urban areas	Small towns and catchment areas for Gr. Cph. and large urban areas	Rural munici-palities	Agricul-tural munici-palities	Outlying munici-palities	Vulner-able munici-palities	Munici-palities facing structural difficul-ties	Concen-tration/ deconcen-tration	Conver-gence/ diver-gence[1]
Base scenario[2]	+	++	+/0	-	-	--	--	Concen-tration	Diver-gence
Market-specific scenarios:									
Deregulation scenario[3]	+	++	+/0	--	--	-	-	Concen-tration	Diver-gence
Industry [4]	0	++	0	-	-	--	--	Concen-tration	Diver-gence
Tourism[5]	+	0	-	-	0	(++)	(+)	Decon-centration	Diver-gence
Political control:									
Welfare scenario[6]	0	+	++	-	0	--	--	Decon-centration	Conver-gence/ Diver-gence
Recr./pop.[7]	+	+	0	-	-	--	--	?	Conver-gence/ Diver-gence
Environmental scenarios[8]	+	+	0	-	--	-	-	Concen-tration	Diver-gence

1) It should be noted that the convergence/divergence conclusions are not based on model calculations, but solely on the authors' own estimates.
2) Hasler et al. 2002.
3) Hasler et al. 2002.
4) Andersen and Christoffersen 2002.
5) Zhang 2001.
6) Dam et al. 1997.
7) Andersen 2002.
8) Hasler et al. 2002.

3.2.1. Market-specific changes

As regards market-specific changes, the research programme analysed the deregulation of the European Union's Common Agricultural Policy (Hasler et al. 2002), probable development trends for industry (Andersen and Christoffersen 2002) and tourism (Zhang 2001). It should be noted that the analyses are not exhaustive because they do not include a number of realistic scenarios, e.g. development changes within other business sectors such as services.

Deregulation scenario

If the EU's Common Agricultural Policy were to be deregulated, Denmark would experience overall growth in production activity and disposable income. Production activity would improve because reducing agricultural production would make room for other types of production activity. At the same time, falling food prices would lead to a rise in actual disposable income. In a regional perspective, "agricultural municipalities" in particular would lag behind the national level of growth and in some situations suffer direct losses, whereas large urban areas, and Greater Copenhagen in particular, would experience growth, due to the benefits of weakened growth in food prices and to production increases in other sectors. In other words, deregulating the Common Agricultural Policy would lead to a concentration of economic activity compared to the baseline.

Whether a deregulation of the Common Agricultural Policy within the EU would lead to rising differences in disposable income depends on whether the population size and composition adapt to this situation. In the short term, the average income in agricultural municipalities would decline, i.e. a divergence trend would emerge. If the population in agricultural areas were to decline, the decline in average incomes would be somewhat limited. And if migration away from the areas is significant, the income differences may be lessened, i.e. convergence would emerge. Although the analyses do not compute population changes that would make it impossible to draw any definitive conclusions regarding convergence/divergence, everything seems to indicate that divergence would prevail.

Industrial scenario
The theme of the industrial scenario (Andersen and Christoffersen 2002) comprises the underlying structural shifts in industrial activity: industrial segments vulnerable to competition, where the educational level of the employees is below average and the export quota is high, are heavily represented in rural areas. In the years ahead, industrial growth in rural areas is expected to weaken, because it cannot be assumed that productivity of these industrial segments vulnerable to competition will continue to grow at the same rate. This is due precisely to the educational gap of these industrial segments vulnerable to competition. As the table shows these shifts will cause the trends in rural areas to weaken, while large urban areas, and Greater Copenhagen in particular, will be strengthened concurrent with the emergence and prevalence of a different type of production activity. Accordingly, this will result in a concentration of economic activity.

Parallel to this, the level of income in the industrial areas will decline. As these areas are below average, the consequence will presumably be a wider spread, i.e. divergence.

Tourism scenario
Within tourism, Zhang (2001) shows that certain rural areas have several advantages, e.g. access to beaches and nature areas. In these rural areas, tourism will have the potential to create jobs and thus retain (some of) the population. As these areas are usually thinly populated and/or have a low per capita level of economic activity per km^2, a favourable trend will lead to deconcentration.

On the other hand, the extent to which jobs in the tourism sector will contribute to convergence is uncertain. Tourism jobs are low paid due to the low level of educational composition components and seasonal dependency. New jobs in the tourism sector would contribute to lowering the average income for people employed in rural areas. For this reason, a trend of diverging living conditions is most probable.

3.2.2. Policy control
Policy-based changes can also affect economic trends.

Welfare scenario
A current problem to resolve is determining how simultaneous reductions in public-sector expenditure and income will affect economic activity. The analysis under the research programme's "welfare scenario" (Dam et al. 1997) showed that a decline in public-sector employment leads to a wage reduction that strengthens the industrial sectors' competitiveness on export markets. Areas with a concentration of jobs within industry achieve economic growth, while areas with many public-

sector jobs will experience a decline. Whether concentration or deconcentration will occur is uncertain.

It is uncertain whether the welfare scenario will affect the distribution of income. On the one hand, this depends on the average income at the new industrial workplaces compared to the existing workplaces and will presumably move towards convergence. On the other hand, it is significant whether an income tax reduction, which leads to divergence, is carried out. In terms of the implications for disposable income, areas with a high level of income will have special advantages because of the tax reduction. And lastly, the effect greatly depends on the emigration/immigration that could be prompted by the welfare scenario, as this process generally tends to even out the changes to a greater or lesser extent.

Recreational scenario
Initiatives for improving the rural areas as places of settlement (Andersen 2002) – e.g. forestation, establishment of recreational areas, etc. – will increase settlement in the areas or will contribute to maintaining the population. A larger population will create jobs, which in turn would strengthen the GDP at factor cost and the disposable incomes. Whether forestation leads to concentration or deconcentration depends on where the forestation is carried out. Also, whether this will contribute to even out the income differences is a question of a) where the forestation is carried out (in high-income or low-income municipalities); b) the average income of the emigrants (high-income groups are probably more willing to move to forested areas than other groups); and c) whether the level of income for service jobs established in the public and private sectors is above or below the average income of the original population.

Environmental scenario
The conclusion of the environmental scenario focusing on the environmental problems relating to agriculture (Hasler et al. 2002) is that the loss of jobs is concentrated in municipalities with a relatively high level of agricultural production. The effects will depend on the wording of the environmental regulation and the type of agricultural product targeted by the regulation, but there is every reason to believe that this will lead to concentration. Depending on the impact of emigration, the environmental regulation will presumably result in divergence.

4. Conclusion

Over the past twenty or thirty years, economic activity has tended to concentrate from rural to urban areas and from small urban areas to large urban areas. At the same time, population growth has shifted from inner urban areas to suburban areas, especially from the centre of Copenhagen to its suburbs. During the first part of the period, the income differences were equalised, i.e. there was convergence. In the late 1990s, the trends have moved towards divergence (for primary income and tax base) and convergence (disposable income).

A projection to 2010 shows that trends continue to move towards concentration. Due to an anticipated growth in demand for highly processed industrial products and for business services, production, income and employment in Greater Copenhagen and large urban areas are expected to grow, whereas small towns and rural areas are expected to have below-average growth. Outlying municipalities and municipalities facing structural difficulties are particularly expected to see substantially lower levels of growth. At the same time, there are many indications that divergence will occur at the same time because the population shifts are not fully assessed as being able to keep up with the concentration process.

Analyses of different realistic *market-specific changes* indicate a trend towards additional concentration, although this scenario is somewhat ambiguous. Parallel to this are the market-specific scenarios that also manifest a predominant trend towards widening income differences, i.e. divergence.

The picture is more complex, however, as regards scenarios expressing *policy control*, as the effects on concentration and deconcentration depend greatly on the content of the policy initiatives.

Whether regional development will be characterised by convergence or divergence will largely depend, however, on how the initiatives are structured and on the population shifts deriving from them. If the population grows in areas where production and employment are concentrated, the average income will not necessarily increase more than the national average and, thus, will not lead to shifts in the distribution of income.

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Kapitel 2

Tendenser i den regionale udvikling i Danmark

Bjarne Madsen og Anne Kaag Andersen

1. Målsætninger for den regionale udvikling

Formålet med denne artikel er primært at se på den regionale udvikling de kommende år. Først foretages en afgrænsning og definition af regional udvikling og hvordan den kan måles. På baggrund heraf gøres en kort status for den regionale udvikling fra 1980 til i dag. Dernæst præsenteres resultaterne af en base-line-fremskrivning af den regionale udvikling frem til år 2010 og analyser af de regionale virkninger af forskellige markedsbestemte udviklingstendenser og af forskellige mulige politiske initiativer/beslutninger. Konsekvenserne af base-linefremskrivning og scenarie-analyserne vurderes i forhold til målsætninger for den regionale udvikling.

1.1. Hvad menes med ”regional udvikling”?

Der er interesse omkring den regionale udvikling i Danmark. Regeringen udtrykte fx i sin regionalpolitiske redegørelse (2002), at ”det er regeringens mål, at den danske befolkning skal sikres gode og ligelige levevilkår, uanset hvor i landet man bor. Regeringen ønsker, at alle områder af landet bliver attraktive områder for udvikling og bosætning, således at der kan oppebæres geografisk spredning af befolkningen og den økonomiske aktivitet. Endelig vil regeringen tilstræbe, at den regionale udvikling på lang sigt fører til mindre ulighed i service, beskæftigelse og økonomiske vilkår i regionerne”[1]. I redegørelsen fremlægges regeringens overvejelser til forskellige tiltag, som kan skabe en bedre regional balance.

Citatet fra indenrigsministeriet udtrykker prisværdig klart, men måske ikke operationelt, hvad der menes med regional udvikling. Første del om gode og ligelige levevilkår er et udsagn om konvergens/divergens, dvs. stillingtagen til hvor store forskellene i indkomst pr. indbygger på tværs af landet som kan accepteres. Anden del handler om problemstillingen koncentration/dekoncentration m.h.t. arbejdspladser og befolkning, dvs. hvad er det mindste eller største antal indbyggere, arbejdspladser mv., som kan accepteres. Tredje pind vedrører koncentration/dekoncentration vedr. service, beskæftigelse og økonomiske vilkår i regionerne – igen spørgsmålet om minimums- og maksimumsgrænser for disse aktiviteter.

1.2. Begrundelser for ønsker om konvergens/divergens eller koncentration/dekoncentration

Målsætningerne for regionalpolitikken – hvordan skal den økonomiske aktivitet være fordelt (koncentration/dekoncentration) og hvor store må indkomstforskellene være (konvergens/divergens) begrundes forskelligt. Et ønske om konvergens tager udgangspunkt i en fordelingspolitisk målsætning om at mindske de regionale forskelle i levevilkår. Omvendt kan ønsket om forøgelse af indkomstforskellene (divergens) begrundes med hensynet til, at der skal være incitamenter til at øge produktionen i områder med høj produktivitet på bekostning af produktion i områder med lavere produktivitet.

Ønsket om koncentration eller dekoncentration begrundes på forskellig måde. Koncentration af den økonomiske aktivitet i store bysamfund eller i områder med specialiseret erhvervsaktivitet tager udgangspunkt i de fordele, som en koncentration i produktion bevirker – fx forøget produktivitet

[1] Tilsvarende overvejelser – om end knap så præcise – kan findes i andre regeringsdokumenter, fx Miljøministeriets forslag til landsplanrededgøelse.

gennem skalafordele, gennem adgang til større arbejdsmarkeder mv. og gennem positive påvirkninger af produktiviteten gennem kontakt mellem virksomheder af samme type eller af forskellig type. Ønske om koncentration kan også begrundes i en målsætning om at fastholde en national kultur ved at styrke de mest bæredygtige dele af kulturen. Omvendt kan ønsket om dekoncentration begrundes med bevarelse af lokalsamfund, som har en betydning kulturelt (fx landdistrikter) eller ønsket om at fastholde befolkningen i udkantsområderne for at modvirke flaskehalsproblemer i bycentrene.

1.3. Hvordan måles regional udvikling?

Der kan opstilles en række forskellige operationelle mål for regional udvikling. De afspejler forskellige funktioner af den økonomiske aktivitet – og kan give (vidt) forskellige resultater.

For det første benytter en række mål for regionaløkonomisk aktivitet regionens eller det lokale områdes funktion som produktionssted, som bopæl og som efterspørgselssted (markedssted). Bruttofaktorindkomsten er eksempel på et mål, som gælder for produktionsstedet, mens disponibel indkomst refererer til bopæl for husholdninger i en given region. Efterspørgslen – fx det private forbrug, investeringer mv. - henføres normalt til efterspørgselsstedet.

Tilsvarende henføres økonomisk aktivitet også til en bestemt aktør i den regionale økonomi – fx producenterne (bruttofaktorindkomsten) eller til institutionerne (husholdningerne). Endelig vælges forskellige mål for økonomisk aktivitet – fx aktørens primære indkomst eller disponible indkomst. Som det vil fremgå senere, kan der drages forskellige konklusioner afhængig af om man ser på den primære indkomst, udskrivningsgrundlaget eller den disponible indkomst.

Valg af udviklingsmål er relevant for hvilke styringsredskaber, som kan bringes i anvendelse (erhvervsfremme, boligpolitik mv.) Hertil kommer, at der kan drages vidt forskellige konklusioner afhængig af valg af udviklingsmål. Derfor er en stillingtagen til hvad der menes med regional udvikling af stor betydning.

I denne artikel belyses den regionale udvikling ved den primære indkomst, udskrivningsgrundlaget og den disponible indkomst. Hermed analyseres den regionale udvikling (koncentration/dekoncentration henholdsvis konvergens/divergens) fra et bopæls synspunkt (modsat arbejdssted eller efterspørgselssted) og set fra husholdningernes synspunkt (modsat ud fra et produktionssynspunkt eller en efterspørgsels-/servicebetragtning).

2. Hvordan er det gået?

Der er gennemført forskellige analyser af den regionale udvikling, nogle med fokus på koncentration/dekoncentration (se fx Madsen m.fl. 1992; Groes 1997; Indenrigsministeriet 1997; Norstrand m.fl. 2001; Madsen & Jensen-Butler 2002; Regeringen 2002) andre med fokus på konvergens/ divergens (se fx Dilling m.fl. 1994; Madsen & Rich 1994; Dilling & Smidt 1997; Groes 1997; Heinesen & Groes 1997; Madsen & Caspersen 1998; Sørensen 1998; Regeringen 2002). Nedenfor opsummeres hovedresultaterne og hovedtendenser vurderes.

2.1. Koncentration – dekoncentration

Ser man på udviklingen i befolkning fra 1980 til 2000 har der for hele landet været tale om en gennemsnitlig årlig vækst på 0.22%. Folketallet i Hovedstaden har haft nogenlunde samme vækst. Men det afspejler nulvækst i Københavns og Frederiksberg kommuner og Københavns amt og en betydelig stigning i omegnskommunerne og det øvrige Sjælland. Folketallet er gået markant tilbage på Lolland og Falster og på Bornholm – både absolut og relativt. I Jylland er folketallet især gået frem i Midt- og Østjylland, mens væksten har været relativt mindre jo mere syd, vest og nord man bevæger sig. Landbrugskommuner, udkantskommuner og udsatte kommuner er alle gået relativt tilbage i folketal. Landkommunerne har et uændret folketal, mens der har været en fremgang i de større byer.

Tabel 1. Gennemsnitlig årlig vækst i folketal og indkomster i perioden 1980-2000 for udvalgte regioner og områder (koncentration/dekoncentration)

	Disponibel indkomst			Primær indkomst			Befolkning		
	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000
Kbh. & Frederiksberg Kommuner og Københavns Amt	5,32	3,68	4,66	6,29	4,27	5,48	-0,35	0,51	-0,01
Frederiksborg og Roskilde	7,11	3,83	5,78	7,76	4,14	6,29	0,52	0,73	0,60
Resten af Sjælland	6,77	3,74	5,55	7,39	4,14	6,08	0,23	0,43	0,31
Lolland, Falster	6,04	3,13	4,86	6,09	2,96	4,82	-0,42	-0,12	-0,30
Bornholm	6,23	3,13	4,98	6,86	2,33	5,02	-0,41	-0,31	-0,37
Fyn	6,83	3,30	5,40	7,57	3,70	6,00	0,21	0,18	0,20
Sønderjyllands Amt	6,94	3,19	5,43	7,14	3,65	5,73	0,01	0,10	0,05
Ribe Amt	7,45	3,31	5,77	8,01	3,60	6,22	0,28	0,21	0,25
Ringkøbing Amt	7,09	3,46	5,62	7,67	3,96	6,17	0,06	0,13	0,09
Århus, Vejle mv.	7,17	3,92	5,86	7,89	4,36	6,47	0,35	0,58	0,44
Nordjyllands Amt	6,90	3,47	5,51	7,44	4,03	6,06	0,08	0,20	0,13
Hele Landet	6,56	3,63	5,37	7,27	4,08	5,98	0,09	0,40	0,22
Hovedstadsområdet	5,87	3,73	5,01	6,79	4,22	5,76	-0,07	0,58	0,19
< 5.000	6,45	3,08	5,09	6,95	3,30	5,48	-0,53	-0,20	-0,40
5-10.000	7,02	3,59	5,64	7,48	4,10	6,11	-0,03	0,20	0,06
10-15.000	7,22	3,59	5,76	7,74	4,07	6,26	0,12	0,34	0,21
15-30.000	6,97	3,48	5,56	7,49	3,83	6,01	0,07	0,22	0,13
30-50.000	6,83	3,60	5,53	7,38	3,93	5,99	0,29	0,42	0,34
50-75.000	8,87	3,83	5,65	7,81	4,24	6,37	0,23	0,45	0,32
>75.000	6,92	3,51	5,54	7,69	3,91	6,16	0,53	0,41	0,48
Hele Landet	6,56	3,63	5,37	7,27	4,08	5,98	0,09	0,40	0,22
Landkommuner	7,04	3,60	5,65	7,55	4,18	6,19	-0,08	0,23	0,05
Landbrugskommuner	7,01	3,52	5,60	7,33	4,10	6,03	-0,17	0,09	-0,07
Udkantskommuner	6,61	3,22	5,24	7,01	3,39	5,55	-0,34	-0,12	-0,25
Udsatte I	6,23	2,96	4,91	6,67	2,82	5,11	-0,53	-0,32	-0,45
Udsatte II	6,40	3,15	5,09	6,75	3,19	5,31	-0,41	-0,15	-0,30

For indkomster er der tale om samme udviklingsmønster: Hovedstaden har i 2000 nogenlunde samme andel af indkomsten som i 1980, men aktiviteterne er forskudt fra centrum til omegnskommunerne. Midt- og Østjylland er gået relativt frem, mens udkantskommuner, udsatte kommuner og kommuner med lavt folketal er gået relativt tilbage. Bornholm og Lolland, Falster er gået relativt tilbage, men udvikling på Fyn og det øvrige Jylland har udviklet sig som landsgennemsnittet.

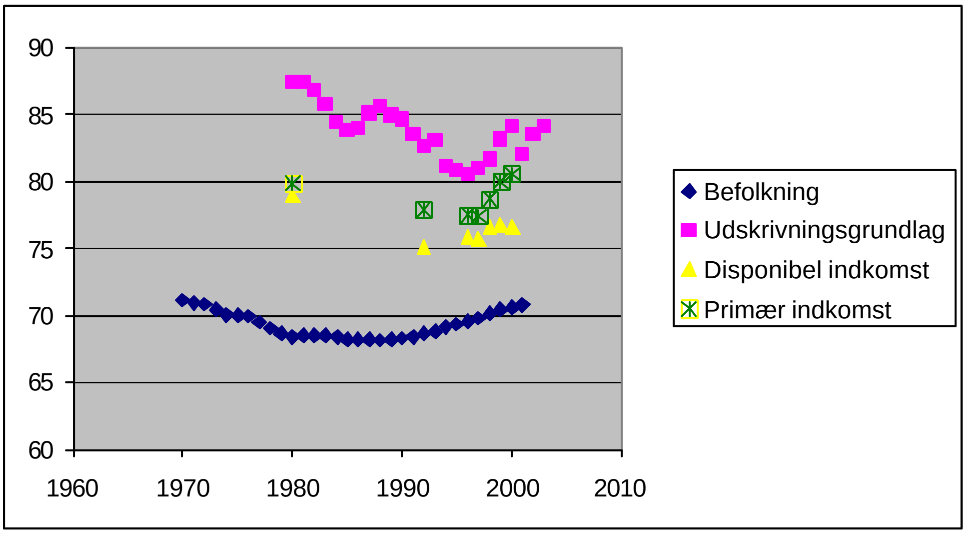
Samlet har der således tilsyneladende været en tendens til koncentration ibåde befolkningstal og indkomster.

Delperioder – strukturbrud?

Som det fremgik af tabel 1, har der været tale om ændring i vækstmønstret i perioden, selvom det kan være svært med udgangspunkt i talmaterialet at fastslå et nøjagtigt brudtidspunkt: Før 1992 var væksten i folketal og indkomster højere i Midt- og Vestjylland, mens hovedstadsområdet havde en svagere vækst. Fra 1992 er væksten i hovedstadsområdet været markant højere end landsgennemsnittet, mens den samlede vækst i Midt- og Vestjylland har ligget på et lavere niveau, men stadig på eller lidt over landsgennemsnittet.

Et mål for samlet koncentration er befolkning pr. arealenhed eller indkomst pr. arealenhed. Hvis denne tæthed er ens i alle arbejdskraftoplande er det udtryk for et dekoncentreret lokaliseringsmønster. I dette tilfælde er spredningen i tætheden (eller variationskoefficienten) lig 0. Hvis den økonomiske aktivitet omvendt er koncentreret til få områder er tætheden forskellig, er spredningen (eller variationskoefficienten) høj og udtrykker dermed koncentration. I figur 1 er vist variationskoefficienten udregnet for pendlingsoplande for indkomster i alt (for perioden 1980-2002) og for indbyggere (for perioden 1970-2000). Hvis man sammenligner 1970 med i dag er der tale om stort set samme grad af koncentration.

Figur 1. Udvikling i koncentration i folketal og indkomster[1]. Variationskoefficient[2] udregnet for pendlingsoplande for indbygger pr. km^2 og indkomst pr. km^2 (koncentration/dekoncentration)



Kilde: AKF's lokaløkonomiske samfundsregnskab, SAM-K – jf. Madsen m.fl. (2001a).

1) Det bemærkes, at data for udskrivningsgrundlaget i 2002 og 2003 er de budgetterede med eventuel korrektion for kommuners valg af statsgaranteret udskrivningsgrundlag.

2) Variationskoefficienten beregnes som spredningen divideret med gennemsnittet. Dermed er variationskoefficienten til forskel fra spredningen uafhængig af den absolutte størrelse af talgrundlaget. Det er derfor velegnet til sammenligninger over tid.

Figuren giver et mere dækkende billede af, hvornår der skete et brud i udviklingen. Og at bruddet ikke kom samtidigt for de forskellige variabler, som indgår i analysen. Af figuren fremgår, at der var tale om dekoncentration i første del af perioden, mens der var koncentration i den anden halvdel af perioden. Omslaget sker først for befolkningen, hvor overgangen fra dekoncentration til koncentration sker i slutningen af 80'erne. For indkomsterne skete omslaget først i midten af 1990'erne. Koncentrationsprocessen er markant både for folketal og for indkomster. Med de tal vi har til rådighed for udskrivningsgrundlaget for 2002 synes tendensen til koncentration at fortsætte.

Beregning af koncentrationsmålet i figur 1 benyttede pendlingsoplande som geografisk enhed. Inden for pendlingsoplande har der været tale om en dekoncentration. Fx har udviklingen inden for de to store områder – hovedstaden og Århus-Vejle – fulgt samme mønster, hvor omegnskommunerne i hovedstadsområdet har haft voksende folketal og beskæftigelse, mens Københavns og Frederiksberg kommuner og til en vis grad Københavns amt har haft relative lavere vækst. Tilsvarende har væksten i det midt- og vestjyske område været koncentreret omkring forstadsområderne/-kommunerne omkring de større byer, især Århus og Vejle.

2.2. Konvergens – divergens

Som det fremgik, har udviklingen i indkomsterne i høj grad fulgt udviklingen i befolkningen, dog med større udsving. Med andre ord vokser de gennemsnitlige indkomst i områder med vigende befolkningsudvikling generelt mere end landsgennemsnittet. Og omvendt områder med lavere vækst end gennemsnittet. Alt andet lige er der altså tale om konvergens.

Tabel 2. Udviklingen i den gennemsnitlige primære indkomst og disponible indkomst 1980-2000 (konvergens/divergens)

	Disponibel indkomst			Primær indkomst		
	1980-1992	1992-2000	1980-2000	1980-1992	1992-2000	1980-2000
Kbh. & Frederiksberg Kommuner og Kbh. Amt	5,68	3,15	4,66	6,66	3,74	5,48
Frederiksborg & Roskilde	6,55	3,08	5,15	7,20	3,39	5,66
Resten af Sjælland	6,53	3,30	5,22	7,14	3,70	5,75
Lolland, Falster	6,49	3,25	5,18	6,54	3,08	5,14
Bornholm	6,67	3,45	5,37	7,29	2,65	5,41
Fyn	6,60	3,11	5,19	7,34	3,51	5,79
Sønderjyllands Amt	6,93	3,09	5,38	7,13	3,55	5,68
Ribe Amt	7,15	3,09	5,51	7,71	3,38	5,96
Ringkøbing Amt	7,02	3,32	5,52	7,60	3,83	6,08
Århus, Vejle mv.	6,80	3,31	5,39	7,52	3,75	6,00
Nordjyllands Amt	6,81	3,26	5,38	7,36	3,82	5,93
Hele Landet	6,46	3,21	5,15	7,18	3,66	5,76
Hovedstadsområdet	5,94	3,13	4,81	6,87	3,62	5,56
< 5.000	7,02	3,28	5,51	7,52	3,51	5,90
5-10.000	7,06	3,39	5,57	7,51	3,90	6,05
10-15.000	7,09	3,24	5,54	7,61	3,72	6,04
15-30.000	6,89	3,25	5,42	7,41	3,61	5,88
30-50.000	6,52	3,17	5,17	7,08	3,50	5,63
50-75.000	6,66	3,36	5,31	7,57	3,77	6,03
>75.000	6,35	3,09	5,03	7,12	3,48	5,65
Hele Landet	6,46	3,21	5,15	7,18	3,66	5,76
Landkommuner	7,12	3,36	5,60	7,63	3,94	6,14
Landbrugskommuner	7,19	3,42	5,67	7,51	4,00	6,10
Udkantskommuner	6,97	3,35	5,51	7,37	3,52	5,81
Udsatte I	6,79	3,29	5,38	7,23	3,15	5,58
Udsatte II	6,83	3,31	5,41	7,19	3,34	5,63

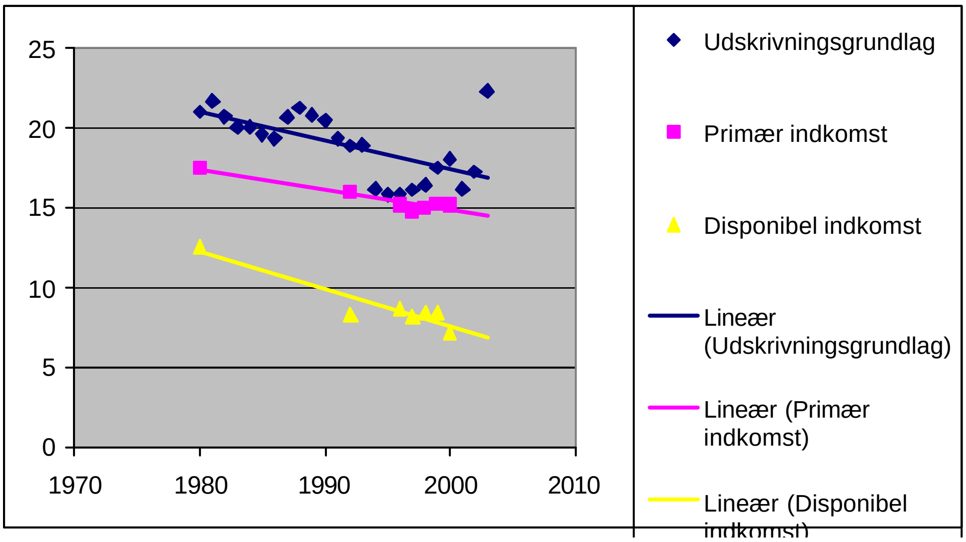
For hele perioden er de gennemsnitlige primære indkomster og disponible indkomster vokset med 5,76% henholdsvis 5,15% pr. år. Den gennemsnitlige primære indkomst er pr. år vokset med 0,3-0,4% mere i det midt- og vestjyske område, mens væksten i hovedstadsområdet pr. år lå ca. 0,3% under. For de større byer var væksten under et ca. 0,3% pr. år over, mens væksten for landkommuner, landbrugskommuner, udkantskommuner og udsatte kommuner er på eller lidt under gennemsnittet hvis man ser på den primære indkomst, mens den er på eller over gennemsnittet, hvis man ser på den disponible indkomst.

Ser man udviklingen i den disponible indkomst følger den generelt udviklingen i den gennemsnitlige primære indkomst dog med en betydelig afdæmpning. Det skyldes, at indkomstfremgang beskattes, og vækst i beskæftigelsen reducerer indkomstoverførslerne.

Dette udviklingsmønster har generelt ført til konvergens i perioden. Hovedstadsområdet, som ligger over gennemsnittet, oplevede især i starten af perioden lavere vækst i den gennemsnitlige indkomst og bidrog dermed til konvergens. Ligeledes lå en stor af kommunerne i det midt- og vestjyske kommuner under landsgennemsnittet i begyndelsen af perioden under landsgennemsnittet. Den voksende økonomiske aktivitet drev gennemsnitsindkomsterne i vejret og bidrog også til indkomstudligningen. Omvendt bidrog en svag udvikling i den primære indkomsten for udkantskommunerne og de udsatte kommuner til en uændret eller lille forøgelse i forskellene, hvilket dog ikke ændrer den generelle tendens til konvergens. De klarede sig bedre, hvis man ser på den disponible indkomst.

Delperioder – strukturbrud?
Ligesom i spørgsmålet og koncentration/dekoncentration er det rimeligt at undersøge, hvor vidt der også sker en ændring omkring 1992 og fremefter. Og om der er tale om nye tendenser i de seneste år. For nøjagtigt at vurdere dette spørgsmål er i nedenstående figur vist udvikling i spredningen i gennemsnitsindkomsterne.

Figur 2. Variationskoefficienter udregnet på kommuneniveau for indkomster[1] pr. indbygger (konvergens/divergens)



Kilde: AKF's lokaløkonomiske samfundsregnskab, SAM-K – jf. Madsen et al (2001a)
1) Det bemærkes, at data for udskrivningsgrundlaget i 2002 og 2003 er de budgetterede med eventuel korrektion for kommuners valg af statsgaranteret udskrivningsgrundlag.

Det fremgår, at der har været tale om stadigt faldende forskelle – eller konvergens – for de disponible indkomster pr. indbygger i hele perioden. For den primære indkomst pr indbygger har der tilsyneladende været tale om et skift omkring 1995 til større spredning – eller divergens – frem til årtusindskiftet. For udskrivningsgrundlaget har der været tale om samme udvikling, hvor konvergens i midten af 1990'erne afløses af divergens. Det sidste tyder på, at det i høj grad er indkomstskattesystemet, som bidrager til, at de disponible indkomster ikke udviser samme tegn på divergens som de primære indkomster.

3. Hvordan vil det gå?

De fleste analyser af den fremtidige regionale udvikling vedrører koncentration og dekoncentration, mens spørgsmålet om konvergens og divergens ikke behandles. Den hidtil mest omfattende vurdering af den regionale udvikling i de kommende år er sket inden for rammerne af forskningsprogrammet "Jordbruget i landdistrikternes økonomi og udvikling" finansieret af Fødevareministeriets Strukturdirektorat.

Inden for forskningsprogrammet er der udviklet et samlet modelsystem bestående af eksisterende modeller for den internationale økonomi (GTAP-modellen) og den danske økonomi (AAGE) og en ny model for den regionale og lokale økonomi (LINE) og landbruget (ESMERALDA). Modelsystemet er benyttet til at foretage en fremskrivning af den regionale udvikling – opstilling af et base-line forløb. Modelsystemet er ligeledes anvendt i en række følsomhedsanalyser, som viser hvorledes den regionale udviklingsforløb vil ændres, hvis forskellige sandsynlige afvigelser indtræffer/realiseres.

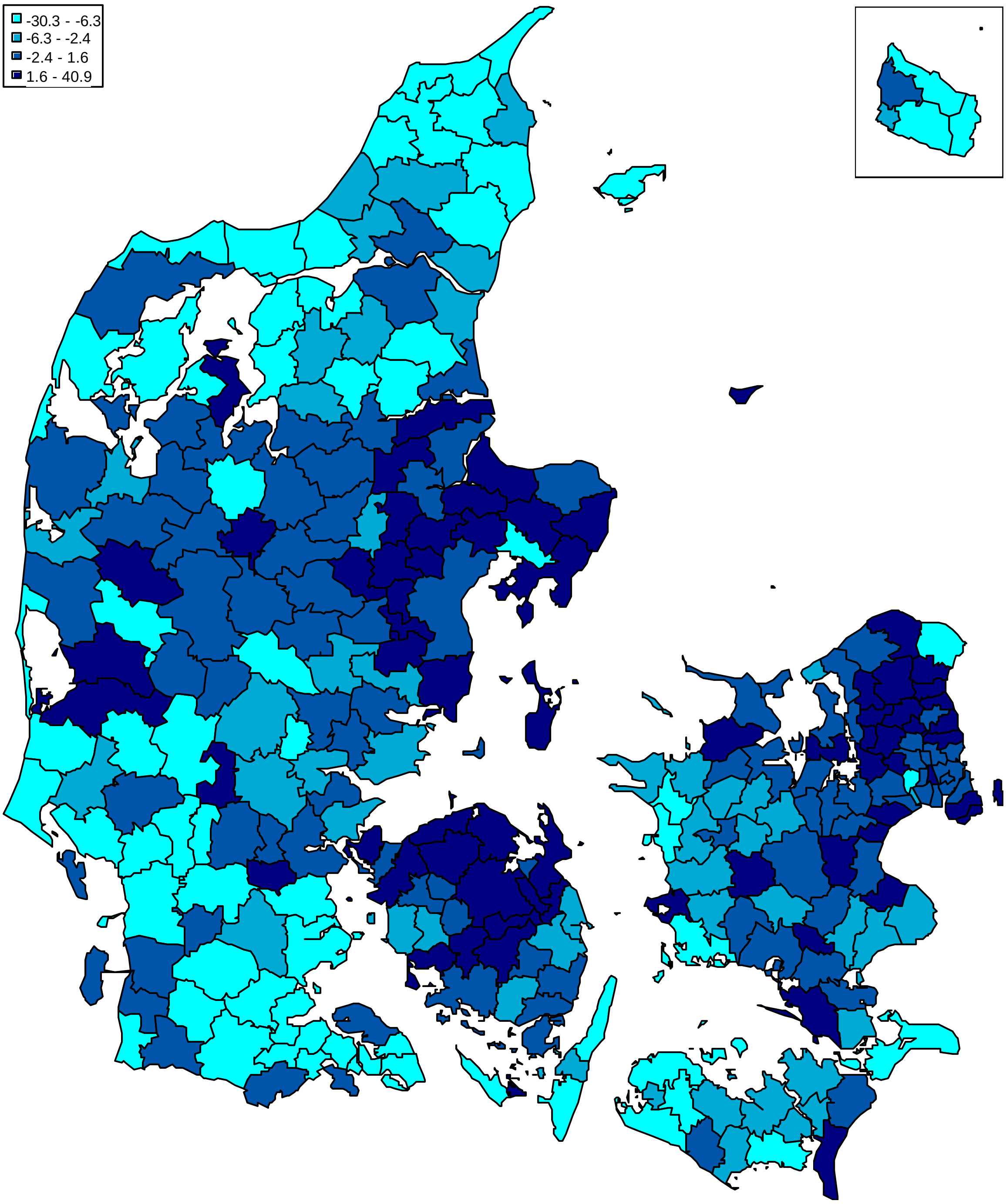
3.1. Base-line scenario

I analyserne af base-line scenariet (Hasler m.fl. 2002) ses alene på udviklingen i indkomster, mens konsekvenser for gennemsnitsindkomsterne ikke er analyseret. Modelberegninger kan derfor alene benyttes til at sige noget om der vil ske en koncentration/dekoncentration, mens spørgsmålet om konvergens/divergens kun kan belyses skønsmæssigt. Det skyldes også, at befolkningsændringer ikke bestemmes i modellen, men er taget fra Danmarks Statistiks befolkningsprognoser.

Koncentration eller dekoncentration

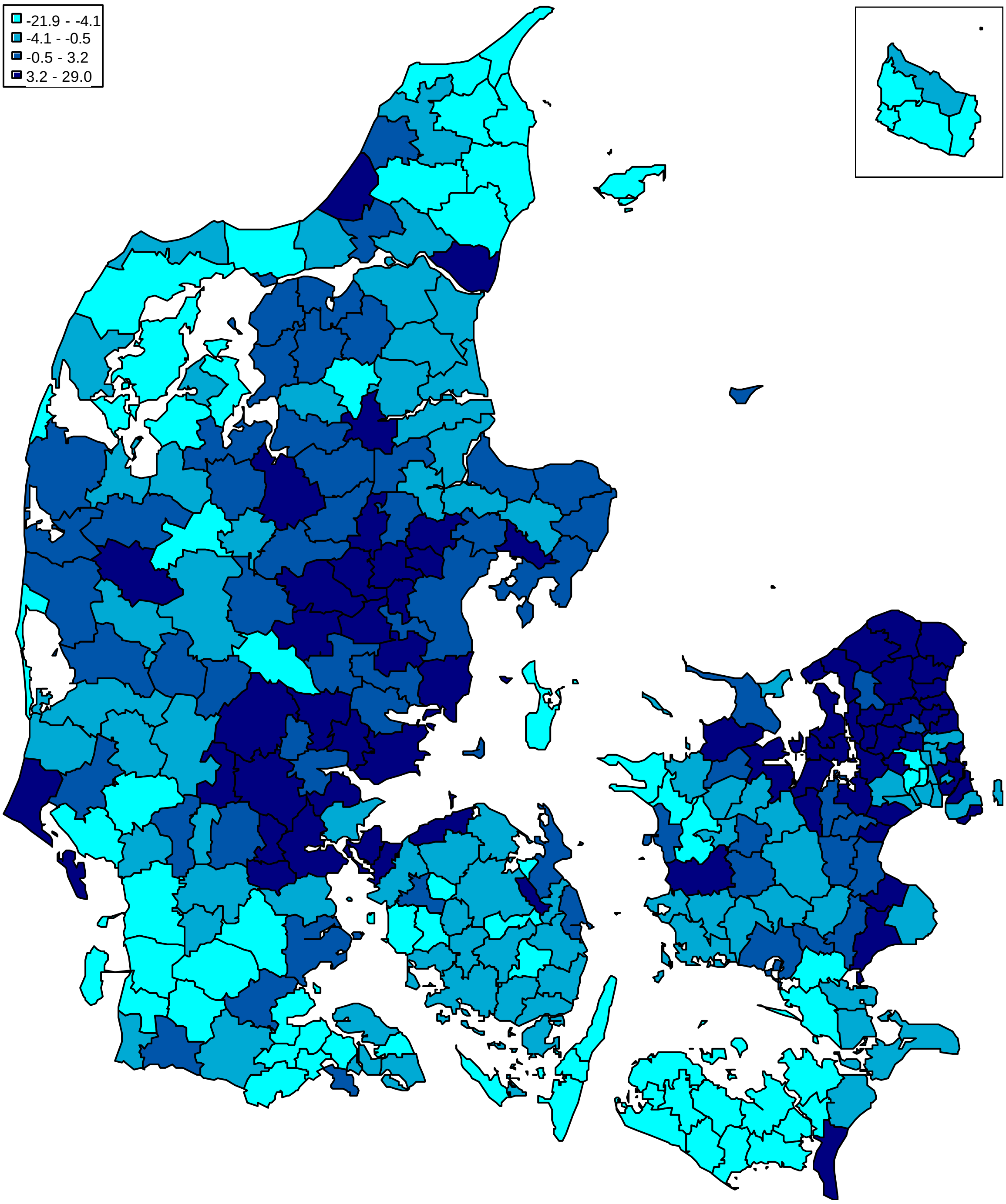
Ser man på base-line tyder alt på, at landdistrikterne får en svagere udvikling, mens hovedstadsområdet og de største byer vil få fremgang. Udviklingen kan illustreres af nogle kort for udviklingen i bruttofaktorindkomsten efter produktionssted (figur 3), den disponible indkomst opgjort efter bopæl (figur 4) og folketallet (figur 5):

Figur 3. Den relative ændring i bruttofaktorindkomst fra 1995-2010, baseline scenario. Afvigelse i procent fra nationalt gennemsnit



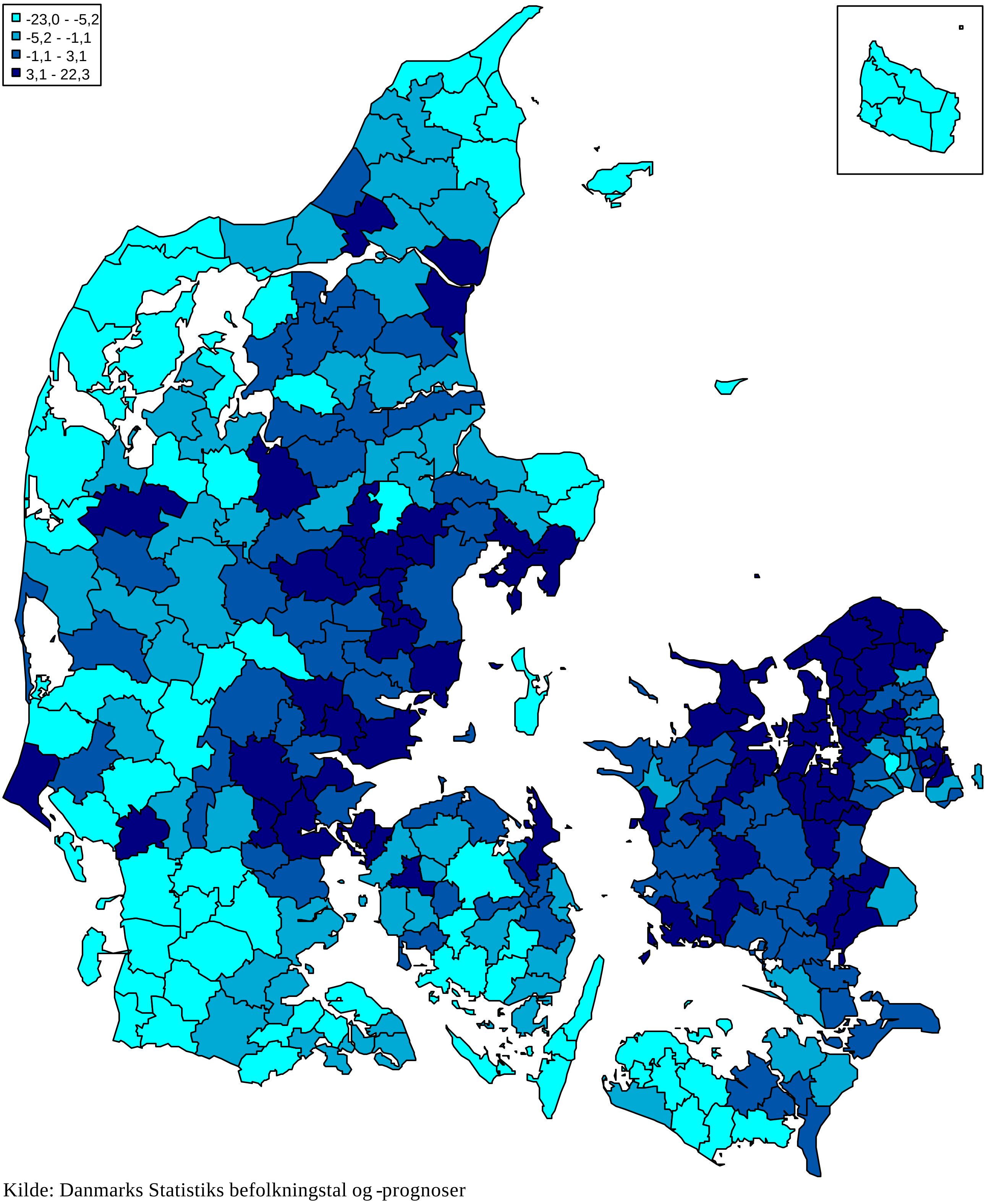
Kilde: beregning med LINE (Madsen m.fl. 2001b; Hasler m.fl. 2002).

Figur 4. Den relative ændring i disponibel indkomst fra 1995-2010, baseline scenario. Afvigelse i procent fra nationalt gennemsnit



Kilde: beregning med LINE (Madsen m.fl. 2001b; Hasler m.fl. 2002).

Figur 5. Den relative ændring i folketal fra 1995-2010, baseline scenario. Afvigelse i procent fra nationalt gennemsnit



Kilde: Danmarks Statistiks befolkningstal og -prognoser

I fremskrivningen er forudsat, at efterspørgslen udvikler sig i overensstemmelse med kendte tendenser, hvor væksten koncentreres omkring udvikling inden for forretningsservice mv. og avancerede industriprodukter, mens udviklingen i efterspørgslen efter fødevarer og industriprodukter med begrænset forarbejdningsgrad er ubetydelig. Samtidig er det forudsat, at produktivitetsudviklingen følger kendte tendenser inden for erhvervene. Befolkningsudviklingen, som især har betydning for udviklingen i de lokale erhverv, følger Danmarks Statistiks befolkningsprognose.

Samlet tyder alt på, at der vil være tendens til fortsat koncentration, om end der ikke er foretaget konsekvensberegninger for spredningen i indkomst pr. km2 – jf. figur 1.

Konvergens eller divergens
Ser man på udviklingen i befolkningen kan man se, at befolkningsforskydningerne i høj grad "følger med" udviklingen i produktionen og indkomst, dog afdæmpet (figur 5). Det betyder, at der er flere til at dele en større kage. Hermed vil vækstområder – i takt med tilflytning – få en relativt lavere vækst i gennemsnitlig indkomst (men stadigt over gennemsnittet), mens tilbagegangsområder – i takt med fraflytning – vil få en større stigning i gennemsnitlig indkomst (men stadigt lavere end gennemsnittet). Det gælder for såvel den gennemsnitlige bruttofaktorindkomst som for den gennemsnitlige disponible indkomst.

Meget tyder således på, at der vil være tale om tendenser til divergens, fordi hovedstadsområdet, som ligger over landsgennemsnittet i indkomst, vil opnå større fremgang end landkommuner mv., som vil opnå tilbagegang i indkomsterne og som ligger under de gennemsnitlige indkomster.

3.2. Alternative scenarier
I forskningsprogrammet er der desuden gennemført en række forskellige delanalyser, som har til formål at vise, hvad der sker, hvis forhold i base-line udvikler sig anderledes end forventet. Der er tale om forandringer, som udspringer af *markedsmæssige tilpasninger* og forandringer, som er resultatet *af politisk styring*. Analysernes resultater kan sammenfattes i nedenstående tabel:

Tabel 3. Konsekvenser for indkomst ved base-line, markedsbestemte scenarier og scenarier for politisk styring

	Hovedstaden og større byer	Mindre byer og oplande til hovedstaden og større byer	Landkommuner	Landbrugskommuner	Udkantskommuner	Sårbare kommuner	Udsatte kommuner	Koncentration/ dekoncentration	Konvergens/ divergens[1]
Basisscenario[2]	+	++	+/0	-	-	--	--	Koncentration	Divergens
Markedsbestemte scenarier:									
Liberalt scenario[3]	+	++	+/0	--	--	-	-	Koncentration	Divergens
Industri[4]	0	++	0	-	-	--	--	Koncentration	Divergens
Turisme[5]	+	0	-	-	0	(++)	(+)	Dekoncentration	Divergens
Politisk styring:									
Velfærdscenario[6]	0	+	++	-	0	--	--	Dekoncentration	Konvergens/Divergens
Rekreativt/bef.[7]	+	+	0	-	-	--	--	?	Konvergens/Divergens
Miljøscenarier[8]	+	+	0	-	--	-	-	Koncentration	Divergens

1 Det bemærkes, at konklusionerne vedr. konvergens/divergens ikke bygger på modelberegninger, men alene egne skøn.
2) Hasler m.fl. 2002.
3) Hasler m.fl. 2002.
4) Andersen and Christoffersen 2002.
5) Zhang 2001.
6) Dam m.fl. 1997.
7) Andersen 2002.
8) Hasler m.fl. 2002.

3.2.1. Markedsbestemte forandringer

Ser man på markedsbestemte forandringer er der i forskningsprogrammet gennemført analyser af liberalisering af EU's landbrugspolitik (Hasler m.fl. 2002), sandsynlige udviklingstendenser for industrien (Andersen & Christoffersen 2002) samt turismen (Zhang 2001). Det bemærkes, at analyserne ikke er udtømmende, fordi en række realistiske scenarier ikke er medtaget, fx ændringer i udviklingen inden for andre erhverv, fx serviceerhvervene.

Liberaliseringsscenario

Hvis der gennemføres en liberalisering af EU's landbrugspolitik, vil der for landet som helhed ske en fremgang i såvel produktion som i disponible indkomster. Forbedringen i produktionen opstår, fordi reduktionen i landbrugsproduktionen giver plads til anden produktion. Samtidig vil faldende fødevarepriser medføre en fremgang i de reale disponible indkomster. Set ud fra en regional betragtning vil især "landbrugskommuner" ligge under den nationale udvikling og i visse situationer lide direkte tab, mens større byer og især hovedstadsområdet vil få fremgang pga. fordelene ved en afsvækket prisudvikling for fødevarer og forøget produktion inden for andre sektorer. En liberalisering af landbrugspolitikken vil med andre ord føre frem en koncentration af den økonomiske aktivitet sammenlignet med base-line.

Om en liberalisering af landbrugspolitikken i EU vil føre til stigning i forskellene i disponible indkomster afhænger af, om der sker en tilpasning af befolkningens størrelse og sammensætning. Umiddelbart vil gennemsnitsindkomsten i landbrugskommunerne falde, dvs. der vil være en tendens til divergens. Hvis befolkningen i landbrugsområderne falder, vil faldet i de gennemsnitlige indkomster til en vis grad blive begrænset. Og hvis fraflytningen er tilstrækkeligt stor, kan der ske en indsnævring af indkomstforskellene, dvs. konvergens. I analyserne er der ikke regnet på ændringer i folketal, der vil gør det umuligt at slutte noget endegyldigt i spørgsmålet om konvergens/divergens, men alt tyder på, at der vil være tale om divergens.

Industriscenario
I industriscenariet (Andersen & Christoffersen 2002) er temaet de underliggende strukturelle forskydninger i industriproduktionen: Den konkurrenceudsatte del af industrien, hvor uddannelsesniveauet blandt de ansatte er under gennemsnittet og eksportkvoten er høj, er stærkt repræsenteret i landområderne. I de kommende år kan det forventes, at udviklingen i industrien i landområderne vil blive svagere, fordi produktivitetsudviklingen ikke kan antages at fortsætte i samme takt i disse konkurrenceudsatte erhverv. Det skyldes netop de konkurrenceudsatte erhvervs uddannelsesmæssige efterslæb. Som det fremgår af tabellen, vil disse skift føre til en afsvækkelse af udviklingen i landdistrikterne, mens de større byer og især hovedstadsområdet vil blive styrket i takt med at en anden type produktion på sigt overtager. Koncentration af den økonomiske aktivitet vil derfor blive konsekvensen.

Sideløbende vil der ske en indkomstnedgang i industriområderne. Da disse områder ligger under gennemsnittet vil konsekvensen formentlig blive forstærket spredning, dvs. divergens.

Turismescenario
Inden for turisme (Zhang 2001) har visse landområder en række fordele, fx adgang til strande og naturområder. For disse landområder vil turismen kunne skabe arbejdspladser og dermed fastholde en (del) af befolkningen. Da disse områder typisk har lavt folketal/lav økonomisk aktivitet pr. kvadratkilometer vil en gunstig udvikling føre til en dekoncentration.

Hvor vidt turistarbejdspladser vil medvirke til konvergens er derimod tvivlsomt. Turistarbejdspladser er lavtlønsarbejdspladser pga. lav uddannelsessammensætning og sæsonafhængigheden. Nye arbejdspladser inden for turismen vil dermed medvirke til at sænke gennemsnitsindkomsten for de beskæftigede i et landområde. En divergens i levevilkårene er derfor mest sandsynlig.

3.2.2. Politisk styring.
Også politisk vedtagne forandringer kan påvirke den økonomiske udvikling.

Velfærdsscenario
En aktuel problemstilling er, hvorledes samtidige reduktioner i offentlige udgifter og indtægter vil påvirke den økonomiske aktivitet. I forskningsprogrammets såkaldte velfærdsscenario (Dam m.fl. 1997) viste analysen, at en nedgang i beskæftigelsen i den offentlige sektor fører til en lønreduktion, som styrker industrierhvervenes konkurrenceevne på eksportmarkederne. For områder med koncentration af arbejdspladser inden for industrien opnås en økonomisk fremgang, mens områder med mange offentlige arbejdspladser oplever tilbagegang. Hvor vidt der sker en koncentration eller dekoncentration er usikkert.

Det er usikkert om velfærdsscenariet vil påvirke indkomstfordelingen. Det afhænger på den ene side af gennemsnitsindtjeningen i de industriarbejdspladser, som etableres i forhold til eksisterende arbejdspladser og som formentlig vil trække i retning af en konvergens. På den anden side har det betydning, hvorledes reduktionen af indkomstskatten, som trækker i retning af divergens, gennemføres. Ses på konsekvenserne for de disponible indkomster opnår områder med højt indkomstniveau særlige fordele pga. skattereduktionen. Og endelig er virkningen meget afhængig af de flytninger, som velfærdsscenariet kunne give anledning til, hvor flytninger generelt har en tendens til at i større eller mindre grad at udligne ændringer.

Rekreativt scenario
Initiativer til forbedring af landområderne som bosætningsområder (Andersen 2002) – fx skovrejsning, etablering af rekreative områder mv. – vil øge indflytningen eller vil medvirke til at fastholde befolkningstallet. Øget befolkning vil skabe arbejdspladser, hvilket igen styrker bruttofaktorindkomst og de disponible indkomster. Om skovrejsning fører til koncentration eller dekoncentration afhænger af, hvor skovrejsning gennemføres. Og om det vil medvirke til at udjævne indkomsterne er et spørgsmål om a) hvor skovrejsningen foretages (i højindkomst- eller lavindkomstkommuner), b) gennemsnitsindkomst for indflytterne (højindkomstgrupper er tilsyneladende mere villige til at flytte efter skovområder end andre grupper) og c) indkomstniveauet for de servicearbejdspladser, som etableres i den offentlige og private sektor, ligger over eller under gennemsnitsindkomsten for den oprindelige befolkning.

Miljøscenariet
I miljøscenariet med fokus på landbrugets miljøproblemer (Hasler m.fl. 2002) er konklusionen, at tab af arbejdspladser er koncentreret til kommuner med relativ høj landbrugsproduktion. Virkningerne afhænger af miljøreguleringens udformning og hvilken type landbrugsproduktion reguleringen rettes imod, men vil efter alt at dømme føre til koncentration. Afhængig af påvirkningen af fraflytningen vil miljøregulering formentlig føre til divergens.

4. Konklusion

I de seneste 20-30 år har der været en tendens til koncentration af de økonomiske aktiviteter fra land til by og fra de små til de større byer. Samtidig er der sket en udflytning fra de centrale dele af byområderne, især fra det centrale København til forstæderne. I den første del af perioden har der været tale om udligning af indkomstforskellene, kaldet konvergens. I slutningen af 1990’erne har der været tendens til både divergens (for den primære indkomst og udskrivningsgrundlaget) og konvergens (den disponible indkomst).

En fremskrivning til 2010 viser fortsatte tendenser til koncentration. Pga. forventet vækst i efterspørgsel efter stærkt forædlede industriprodukter og forretnings- og erhvervsservice forventes produktion, indkomst og beskæftigelse i hovedstadsområdet og de større byer at vokse, mens de mindre byer og landområderne forventes at have mindre vækst end gennemsnittet. Især udkantskommuner og udsatte kommuner forventes at have en betydeligt lavere vækst. Samtidig tyder meget på, at der samtidig vil være tale om divergens, fordi befolkningsforskydninger ikke fuldt vurderes at kunne følge med koncentrationsprocessen.

Analyser af forskellige realistiske *markedsbestemte forandringer* viser tendens til yderligere koncentration – om end billedet ikke er entydigt. Parallelt hermed er der i de markedsbestemte scenarier også overvejende tendens til forøgelse af indkomstforskellene, dvs. divergens.

I scenarier som udtrykker *politisk styring* er billedet mere sammensat, idet virkningerne både på koncentration/dekoncentration meget afhænger af udformningen af de politiske tiltag.

Hvor vidt den regionale udvikling vil blive præget af konvergens eller divergens afhænger dog i høj grad af, hvorledes initiativerne udformes og de afledte befolkningsforskydninger. Hvis folketallet vokser i områder med koncentration af produktion og beskæftigelse, vokser gennemsnitindkomsten ikke nødvendigvis mere end landsgennemsnittet og skaber dermed ikke forskydninger i indkomstfordelingen.

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Section 3:

Decomposition analysis: an extended theoretical foundation and its application to the study of regional income growth in Denmark

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Decomposition analysis: an extended theoretical foundation and its application to the study of regional income growth in Denmark

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Abstract. The paper presents an extended interregional social accounting matrix (SAM) framework, derived from a Danish interregional computable general equilibrium (CGE) model, as the basis for a decomposition of regional income growth in Denmark in the period 1980 – 98. The decomposition analysis indicates that there is some evidence for a reversal in the trend of location of economic activity in Denmark in the 1990s and provides evidence on the causes of this trend reversal.

1 Introduction

The principal aim of this paper is to examine and explain changes in regional income distribution in Denmark in the period 1980 – 98 through the use of decomposition analysis. A second aim is to extend decomposition of regional income growth from the more usual input – output (IO)-based approach to a multiregional and social accounting matrix (SAM)-actor-based approach, which has its roots in a computable general equilibrium model. A third aim is to formulate the decomposition method in general terms, indicating its potential use with different types of regional models.

It is widely believed that the pattern of regional growth in Denmark was subject to a major transformation or trend shift during the last two decades of the last century. In brief, in the 1980s, rural and more peripheral regions exhibited higher rates of growth than urban and more central regions. There seems to be some evidence of a structural break in this pattern of growth during the 1990s, with reversal of the overall growth pattern. The focus of the paper is on the concentration or dispersal of economic growth or the issue of volume of economic activity according to region. Per capita income growth (usually referred to as regional convergence or divergence) is not dealt with here, as the prime interest is in changes in the spatial distribution of economic activity. However, the overall approach could also be used for an analysis of convergence.

In the paper we examine evidence for such a structural break and attempt to identify its possible causes. Different regional economic variables can be examined using decomposition analysis. In this study, three different regional income variables have been chosen: earned income (total and total by sector) according to place of production, disposable income (total) according to place of residence and local authority tax revenue (total) according to place of residence.

The use of an interregional and SAM-based model is demonstrated in the decomposition—a model which is a submodel of the Danish Interregional Computable General Equilibrium (CGE) model, LINE. As opposed to most decomposition analyses, it now becomes possible to identify how much of regional income growth can be attributed to such factors as final demand, regional costs and prices, interregional spillover, and feedback effects from growth in other regions, as well as the effects of nonmarket-based determinants of income, such as taxes and income transfers.

We also present a general formulation of the decomposition problem as it relates to the type of model used in the decomposition. In order to avoid interaction between endogenous and exogenous variables decomposition should be undertaken using reduced-form rather than structural-form models. If decomposition is undertaken using a model in structural form, as an alternative to solving the model analytically as a reduced-form model, the decomposition can be performed on the basis of a series of multiplier experiments. It is argued in this context that, given a structural-form approach, the basic theory underlying the economic model employed to explain the growth process can, in some circumstances, be used to determine the order in which exogenous variables are introduced into the decomposition.

First, decomposition analysis is discussed in relation to regional models. In particular, the issues which arise when the model is in structural form rather than reduced form are examined. This is followed by a discussion of the interregional CGE model LINE, whose interregional and SAM framework is used as the basis for the decomposition. Finally, decomposition analysis based upon this model structure is used to analyse and explain patterns of regional income growth in Denmark.

2 Decomposition analysis and regional growth

Decomposition techniques have been used extensively in regional economics. Shift-share analysis is an early example of the technique (Dinc et al, 1998; Stevens and Moore, 1980). Regional IO models have frequently been used as the basis for decomposition (see, for example, Dewhurst and Jensen, 1995; Dietzenbacher, 2001; Wolff, 1985). A decomposition analysis incorporating interregional feedback effects has been undertaken by Kagawa et al (2004). In the related field of environmental impact analysis the technique has been used to analyse changes in emissions (De Haan, 2001; Wier, 1998).

Decomposition analysis is an exercise in comparative statics, which seeks to explain changes in a variable over time through the use of a number of factors which are assumed to determine the changes in the values of the variable to be explained. The contributions of the individual factors to changes in the variable of interest are estimated. Although the decomposition technique often is presented as a pure accounting technique, it does in fact imply the existence of an underlying model, which may in its simplest form be an accounting type of model. In contrast to econometric analysis, full time-series data are not required, only data for an initial year and a final year.

Although it seems that data requirements in decomposition analysis are more limited than in other approaches to analysis of economic change, a number of important problems related to the underlying economic model exist. First, there is the issue of model complexity, in which the use of a limited number of variables, derived from a relatively simple model, provides an insufficient explanation of economic change. Models based upon the new economic geography will probably provide better results when used in a decomposition analysis than the straightforward IO model. For example, in the case of the type-I multiplier model, induced effects are absent, thereby implying neglect of the relationship between income and private consumption as an explanation for economic change.

Second, there is a problem related to the mathematical form of equations in the model, in which pure linear relationships are usually regarded as inadequate. The conventional IO model is based upon linear production functions with constant returns to scale, whereas in the new economic geography nonlinearities are commonly assumed.

Third, it is necessary to transform a fully specified model in structural form to a reduced-form model with only exogenous variables on the right-hand side of the equation. This can be done either through a mathematical solution or through the use of simulation methods.

2.1 Decomposition and the theoretical foundation

Decomposition is based upon a number of principles. As Rose and Casler (1996) note, splitting an identity into its components should ensure that the individual component terms are mutually exclusive and exhaustive, that is, that contributions from the individual components or factors are completely separable, and that together they account for the total change in the variable.

In order to clarify these issues, a general formulation of the decomposition problem is presented. Assuming that we wish to analyse growth in economic activity according to region, one point of departure is the change in economic activity, measured as volume of earned income according to place of production:

$$\Delta y = y_{t_1} - y_{t_0} \ , \tag{1}$$

where y is earned income and t_1 and t_0 are points of time.

In the following discussion a regional economic model in its structural form is designated as $\mathrm{M^S}$. Model M is a reduced-form, single-equation model, derived from $\mathrm{M^S}$:

$$y = \mathrm{M}(E_1, E_2, \ldots, E_j, \ldots, E_N) + U \ , \tag{2}$$

where E_j is an exogenous variable related to the jth group of variables and U is the model error. Taking regional earned income as the variable to be explained, changes in earned income are therefore given by:

$$\Delta y = [\mathrm{M}(E_1^{t_1}, E_2^{t_1}, \ldots, E_N^{t_1}) + U^{t_1}] - [\mathrm{M}(E_1^{t_0}, E_2^{t_0}, \ldots, E_N^{t_0}) + U^{t_0}] \ . \tag{3}$$

Equation (3) is a model based upon total changes which involves changes in all explanatory variables taken over two points of time. The model can then be used to explain growth in the variable of interest (in this case earned income) between two points of time.

Partial analysis examines the impact of *one* selected factor or group of variables. In this case the decomposition, if only E_1 changes, is as follows:

$$\Delta y = [\mathrm{M}(E_1^{t_1}, E_2^{t_0}, \ldots, E_N^{t_0}) + U^{t_0}] - [\mathrm{M}(E_1^{t_0}, E_2^{t_0}, \ldots, E_N^{t_0}) + U^{t_0}] \ ,$$

or

$$\Delta y = \mathrm{M}(E_1^{t_1}, E_2^{t_0}, \ldots, E_N^{t_0}) - \mathrm{M}(E_1^{t_0}, E_2^{t_0}, \ldots, E_N^{t_0}) \ . \tag{4}$$

It is assumed that the error term U^{t_0} is independent of the change in E_1.

Equation (4) is one element of change in equation (3). Each E_i is entered successively into equation (3) by addition followed by the subtraction of corresponding exogenous variables in model calculations for two points of time. The sum of all of these steps constitutes a total decomposition of economic activity as each partial decomposition in equation (4) is substituted into equation (3). Thus, total decomposition decomposes economic activity into the following components:

$$\Delta y = [\mathrm{M}(E_1^{t_1}, E_2^{t_1}, \ldots, E_N^{t_1}) + U^{t_1}] - [\mathrm{M}(E_1^{t_0}, E_2^{t_0}, \ldots, E_N^{t_0}) + U^{t_0}] \ ,$$

which can be rewritten

$$\begin{aligned}\Delta y \;=\; & \mathrm{M}(E_1^{t_1}, E_2^{t_0}, E_3^{t_0}, \ldots, E_N^{t_0}) - \mathrm{M}(E_1^{t_0}, E_2^{t_0}, E_3^{t_0}, \ldots, E_N^{t_0}) \\ & + \mathrm{M}(E_1^{t_1}, E_2^{t_1}, E_3^{t_0}, \ldots, E_N^{t_0}) - \mathrm{M}(E_1^{t_1}, E_2^{t_0}, E_3^{t_0}, \ldots, E_N^{t_0}) \\ & + \mathrm{M}(E_1^{t_1}, E_2^{t_1}, E_3^{t_1}, \ldots, E_N^{t_0}) - \mathrm{M}(E_1^{t_1}, E_2^{t_1}, E_3^{t_0}, \ldots, E_N^{t_0}) \\ & + \ldots \\ & + \mathrm{M}(E_1^{t_1}, E_2^{t_1}, E_3^{t_1}, \ldots, E_N^{t_1}) - \mathrm{M}(E_1^{t_1}, E_2^{t_1}, E_3^{t_1}, \ldots, E_N^{t_0}) \; . \qquad (5)\end{aligned}$$

In a total analysis, economic growth from year t_0 to year t_1 is decomposed using model M to calculate the effects of each step in the decomposition, ending with the total change in economic activity. Starting with the impacts of changes in the exogenous variables of group 1, the model M is run with the values of the exogenous variables in group 1 set equal to those of the final year and all other exogenous variables set at values corresponding to the first year. The effect of the exogenous variables of group 2 is calculated by including the final year values for these variables and the first year values for all other following variables. Consecutively, the effects of economic changes of other exogenous variables can be included in the same manner. In this way, the total effect is divided into N partial effects and is termed cumulative decomposition analysis.

As noted above, cumulative decomposition faces the basic problem that the effects of the individual component do not necessarily sum to the total. This is the case when the difference between model errors $(U^{t_1} - U^{t_0})$ is not equal to zero. Here, correction can be made by using different proportional adjustment methods. Model errors either reflect the fact that the model used in the decomposition does not replicate empirical data because of statistical error or, more commonly, because the model is incomplete and, as such, misspecified.

Another basic problem in cumulative decomposition is that results are affected by the order in which the components are applied. This is because the difference between the t_0 level and the t_1 level of any one factor influences the calculation of the effects of succeeding factors.

In order to avoid the problem of order, decomposition can be undertaken as a set of isolated calculations, in which the exogenous variables are assigned their t_1 values and the calculations are performed on the t_0 values for each step, starting at the beginning each time. One set of changes does not, therefore, affect the calculation of any other set of changes. The disadvantage of this method is that the sum of the isolated elements of the decomposition will not necessarily (and will not usually) equal the total growth in the variable in question—earned income or alternative income measures in this case. It is difficult to interpret the positive or negative residual appearing from this type of analysis.

Returning to the question of cumulative decomposition, there are in principle $N!$ permutations (orderings) of N exogenous variables. In principle each of these $N!$ orderings give a different result. One solution to the problem of the existence of multiple equivalent decomposition forms is to take the average of all $N!$ decompositions (Dietzenbacher and Los, 1998). A more efficient but still purely quantitative approach has been proposed by De Haan (2001), who shows that the average of two decompositions which are mirror images of each other is close to the global average.

A more contentious approach is to rely upon explicit or implicit causal chains in the model being used. In a true simultaneous model causal sequences are impossible to identify so that choice of order in a decomposition becomes a matter of convention. However, even in this case it sometimes seems reasonable to let the order of inclusion of exogenous variables be influenced by theoretical priorities reflecting importance in relation to the variable to be explained. For example, direct effects can be placed before derived effects, as is the case with changes in tax rates and benefits in relation to changes in disposable income. Another example is the Keynesian demand-driven model, which starts with changes in demand and then generates production and income.

In addition, there is a middle ground where it may be reasonable to identify causal sequences. If the model has an explicit temporal dimension—for example, such that changes in production result in changes in emissions to the environment—then it may be possible to identify a causal sequence, which can be reflected in the decomposition. There is an implicit causality assumed in the case of shift-share analysis, in which the decomposition sequence represents an underlying implicit and simple hierarchy of causality, such that national growth in employment reflected at the regional level is afforded theoretical primacy, this then being affected by regional sectoral composition and by the regional (residual) growth effects.

In the following discussion a simultaneous model is used as the basis for the decomposition. However, the elements which have a direct effect on the variable to be explained are entered first.

A further problem arises if equations based on a model in structural form rather than reduced form are used. In a structural-form model the left-hand-side (endogenous) variable depends on both endogenous and exogenous variables on the right-hand side of the equation:

$$y = \mathrm{M}^{\mathrm{S}}(E_1^{\mathrm{X}}, E_2^{\mathrm{X}}, \ldots, E_i^{\mathrm{X}}, \ldots, E_N^{\mathrm{X}}, E_1^{\mathrm{N}}, E_2^{\mathrm{N}}, \ldots, E_j^{\mathrm{N}}, \ldots, E_M^{\mathrm{N}}) + U \ , \qquad (6)$$

where E_i^{X} is an exogenous variable related to the ith group of variables, and E_j^{N} is an exogenous variable related to the jth group of variables.

This can lead to errors in the decomposition because if the equations are used in structural form there can be interaction between the right-hand-side endogenous and exogenous variables. Therefore, unique results can only be achieved if the decomposition is based upon reduced-form equations. Alternatively, if the model in structural form has not been transformed to reduced form, the decomposition can be carried out using numerical solution methods, which is the approach employed in this study.

An important issue in decomposition is the assumption of independence amongst the determinants of structural change (Dietzenbacher and Los, 2000). In order to ensure that the results of decomposition analysis are unbiased, it is necessary to identify the explanatory variables which are truly independent (exogeneity) and those which are determined by summing up constraints (endogeneity). In the final analysis this relates to a correct model specification, in which the consequences of changing a single coefficient exogenously, for other coefficients in the model, are fully specified.

This discussion links into a further issue, that of the choice between single-equation models, estimated using econometric techniques, and the use of multiple-equation models in structural form. In the literature there is a wide-ranging discussion concerning the advantages and disadvantages either of using multiple-equation models formulated in structural form of using single equation models. In the analysis of regional growth a structural model permits inclusion of more factors relevant to the explanation of patterns of regional growth and is therefore to be preferred (Madsen and Jensen-Butler, 1999). The principal reasons for using multiple-equation models are an improved capacity for the formulation of an overall and consistent theoretical framework to explain the behaviour of regional actors as well a the fact that regional economic growth is a very complex process involving a large number of subprocesses and different actors in the regional economy, with interaction between them. In single-equation models problems arise concerning the theoretical base of reduced-form models, which is often unclear. A number of changes in the regional economy are represented by very few variables, a feature which introduces the risk that insights into the detailed workings of the regional economy will be lost. On the other hand, the risks involved with the use of multiple-equation models include data problems, failures in model selection and specification, and lack of clarity. A general discussion of the advantages of using models in structural form is provided by Lucas (1976).

3 LINE and decomposition

The decomposition presented here is undertaken using one of the main components of an interregional general equilibrium model, LINE, which has been developed at subregional or local level. The full documentation of the model equations is available in Madsen and Jensen-Butler (2004a; 2004b) and Madsen et al (2001a).

3.1 The LINE model

LINE is a general equilibrium model which contains two basic circles—one relating to real economic activity, and the other, which interacts with the real circle, relating to costs and prices. The general model structure shown in figure 1 is based upon the real (Keynesian) circle employed in LINE. The core of the real circle is an interregional and SAM-based IO model with fixed coefficients for a given year (Madsen et al, 2001a; 2001b).

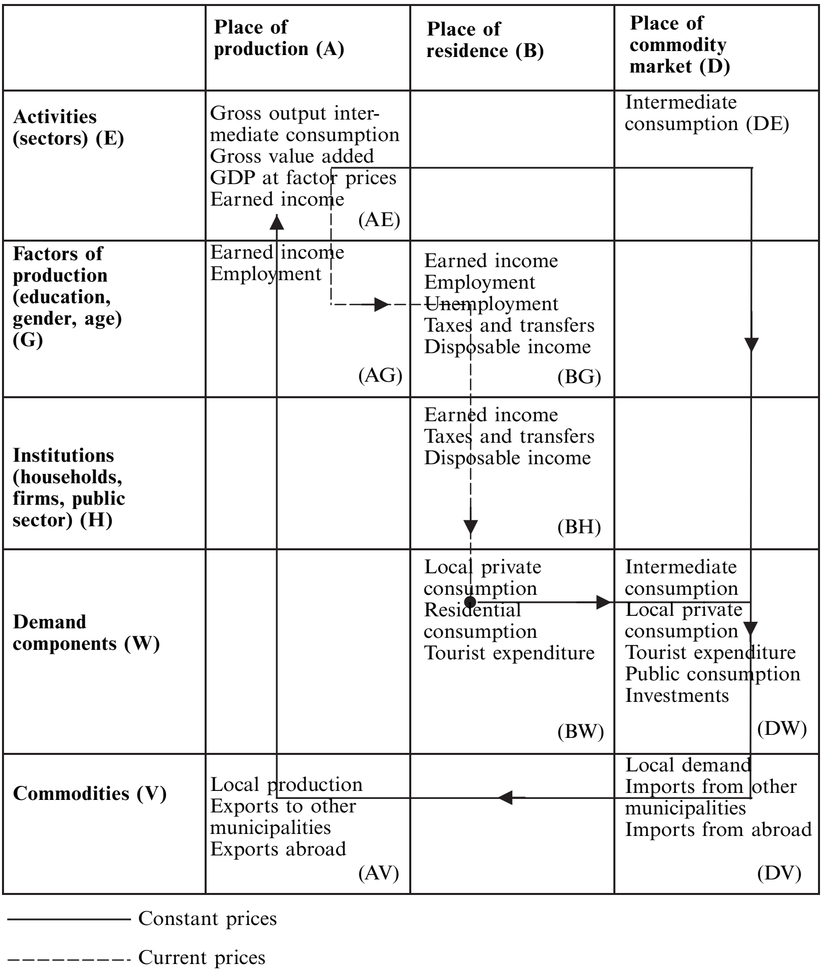

Figure 1. A simplified version of LINE: the real circle.

The coefficients can, however, change over time. The horizontal dimension is spatial: place of work (denoted A), place of residence (B), and place of commodity market (D). Production activity is related to place of work. Factor rewards and income to institutions (households, firms, public sector) are related to place of residence, and the demand for commodities is assigned to the place of commodity market. Thus, the model incorporates the three basic spatial categories necessary to examine the workings of the spatial economy. The vertical dimension is more detailed and follows with its five-fold division the general structure of a SAM model (see, for example, Hewings and Madden, 1995). Production is related to activities; factor incomes arise from activities according to sector; they are earned by factors of production, in this case labour, grouped by qualification; labour is related to institutions, in this case households; demand for commodities is related to wants (aggregates of commodities or components of final demand and intermediate consumption); finally, commodities are defined, irrespective of use.

The real circle corresponds to a straightforward Keynesian model and moves clockwise in figure 1. Starting in cell AE in the upper-left corner, production generates factor incomes in basic prices—including the part of income used to pay commuting costs. This factor income is transformed from sectors (AE) to place, sex, age, and educational groups (AG). Factor income is then transformed from the place of production (AG) to the place of commodity market (BG) through a commuting model. Employment follows the same path from sectors (AE) to sex, age, and educational groups (AG) and further from the place of production (AG) to the place of residence (BG). Employment and unemployment are then determined (BG).

Disposable income is calculated in a submodel in which taxes are deducted and transfer and other incomes are added. Disposable incomes are distributed from factors (BG) to households (BH). This is the basis for a determination of private consumption in market prices, according to place of resident (BW). Private consumption is assigned to the place of commodity market (DW) through the use of a shopping model. Private consumption, together with intermediate consumption, public consumption, and investments, constitute the total local demand for commodities (DV) in basic prices through a use matrix. In this transformation from market prices to basic prices (from DW to DV) commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and from abroad, in addition to local production. Through a trade model, exports to other regions and production for the region itself is determined (from DV to AV). By adding exports abroad, gross output by commodity is determined. Through a reverse make matrix the cycle returns to production by sector (from AV to AE).

As noted above, a central issue in the use of models in decomposition analysis is the question of dependency amongst apparently exogenous variables (Dietzenbacher and Los, 2000), which would distort the results. In LINE a strict accounting principle has been adopted, which ensures that summing-up constraints are met. For example, the coefficients of value added are not exogenous, but are calculated residually as one minus the sum of the coefficients of intermediate consumption.

3.2 LINE applied

The point of departure for the decomposition study is equation (5). The three variables of interest in this study (the left-hand-side variables) are (1) earned income (total and total by sector) according to place of production, (2) disposable income (total) according to place of residence, and (3) local authority tax revenue (total) according to place of residence. These three variables are determined within the model. In order to specify the nature of the decomposition used, M on the right-hand side of the equation must be specified as well as the exogenous variables which constitute the arguments in the decomposition equation and the order in which they are introduced.

Concerning the choice of model, three important simplifications have been employed. First, only the real circle of LINE has been used and the cost – price variables have been treated as exogenous. In this version, based only on the real circle, LINE can be characterised as an extended interregional IO model. This means that all transformations between different spatial units (the horizontal dimension in figure 1) and between different SAM actors (the vertical dimension in figure 1) are based upon linear relationships with fixed coefficients.

Second, referring to equation (6), LINE in the structural form (M^S) has been used, thereby generating the contribution from each component in the decomposition through numerical simulation using the model. Ideally, the reduced-form version of LINE (M), based upon an analytical solution of the model (see Madsen and Jensen-Butler, 2004b) should be used in the decomposition. However, the analytical solution is very unwieldy, which makes the numerical solution much more attractive, and the information content of the analytical solution is restricted to the sign rather than the size of the contribution of the component in the decomposition.

Third, and ideally, the full version of LINE, including both the real circle and the price – cost circle, should have been used. However, because of data problems associated with determining the historical values of cost and price variables by region, it is at present not possible to include changes in costs and prices as an explanatory factor in the decomposition. The full version of LINE with both circles has been used in a number of studies (Kveiborg et al, 2004; Madsen and Jensen-Butler, 2004a) in which time-series data on regional costs and prices were not required.

Jensen-Butler et al (2002) used an earlier and simple version of LINE as the basis for a decomposition analysis designed to assess the effects of the welfare state on income growth in Denmark according to region, and they conclude that less than 50% of income growth in rural areas is attributable to changes in public sector activity or taxation and income transfers, as opposed to market-related mechanisms. The present version has improved on this analysis, as it involves the entire interregional and inter-SAM-actor system, and at the same time it highlights contributions from components of regional demand which are determined by cost and price variables, such as export and private consumption.

The version of LINE used in this study shows how structural factors contribute to regional growth, as noted above, particularly in relation to interregional and inter-SAM-actor relationships. This requires a high degree of flexibility with respect to definitions. LINE is generally flexible with respect to aggregation on each of its dimensions. The version used here involves spatial units which are labour market areas, these being aggregates of municipalities (kommuner), as shown in figure 2. It is a spatial aggregation which is used in analyses involving place of production, place of residence, and place of commodity market. 'Outside the regions' (principally crude-oil production and embassies) covers only places of production and places of commodity markets.

The present version of LINE uses twelve sectors, shown in table 1, aggregated from 130.

LINE also subdivides the labour force by age (seven groups), gender (two groups), and education (five groups). Household types are divided into four categories by composition, and there are thirty-one components of final demand (private consumption has thirteen components, government consumption has eight, and investment has ten). Commodities are aggregated into twenty groups.

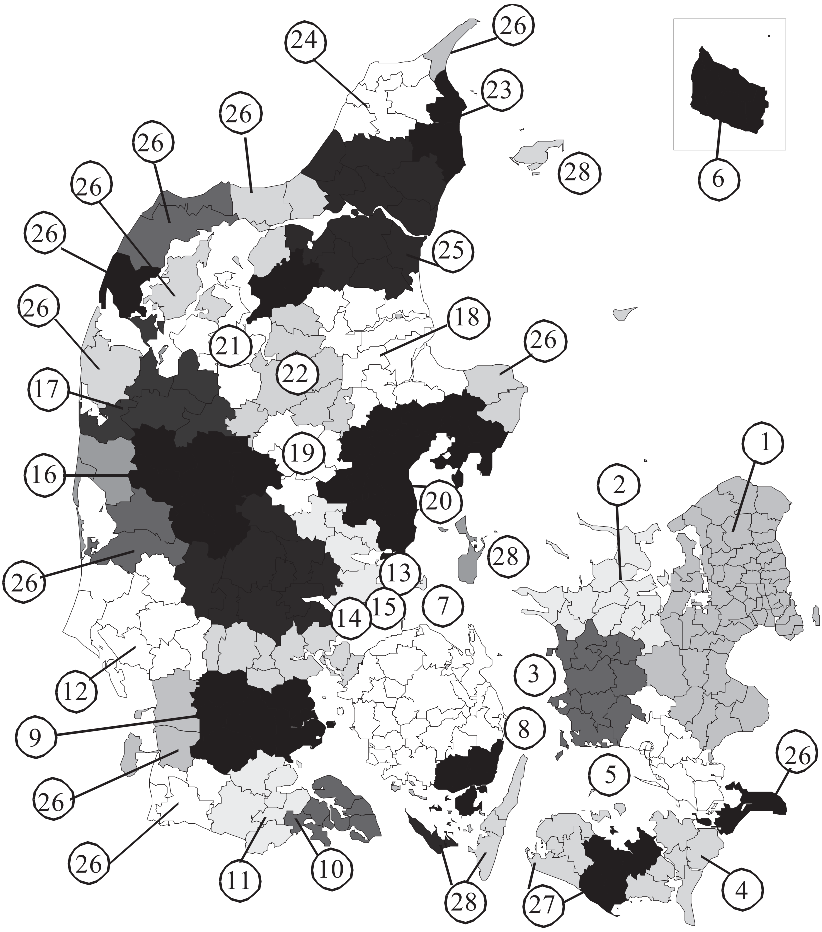

Figure 2. Labour market areas in Denmark (Miljøministeriet, 1994): 1, Greater Copenhagen; 2, Holbæk; 3, Korsør; 4, Nykøbing F.; 5, Næstved; 6, Bornholm; 7, Odense; 8, Svendborg; 9, Haderslev; 10, Sønderborg; 11, Åbenrå; 12, Esbjerg; 13, Horsens; 14, Kolding; 15, Vejle; 16, Herning; 17, Holstebro; 18, Randers; 19, Silkeborg; 20, Århus; 21, Skive; 22, Viborg; 23, Frederikshavn; 24, Hjørring; 25, Ålborg; 26, Others; 27, West and Mid-Lolland; 28, Small Islands; 29, 'outside the regions'.

Table 1. Sectors used in LINE for decomposition analysis.

Sector description
Agriculture, fishing, and quarrying
Extraction of crude oil, natural gas, etc
Manufacturing industry
Utilities
Construction
Wholesaling, retailing, hotels, restaurants
Transport
Financial intermediation and insurance, etc
Other services
Imputed unpaid financial intermediate services
Production of unspecified products 1
Production of unspecified products 2

3.3 Groups of exogenous variables used in the decomposition and their order of introduction

The exogenous variables used in the decomposition [equation (5)] have been placed in one of fifteen different categories that constitute the fifteen elements used in an explanation of the process of regional economic growth. These groups of variables are shown in table 2. The order in which they are introduced follows the order shown in the model circle in figure 1, starting with the elements directly determining demand, population, and commuting in AG and BG (element a), continuing through income transfer and tax determination to disposable income and private consumption at place of residence BW (elements b, c, and d). Private consumption in total and by component are then determined (elements f, g, and h). After transformation from place of residence to place of commodity market (DW), private consumption is combined with other types of demand, such as intermediate consumption, government consumption and investment, all summing to local demand by commodity DV (elements e, i, j, and m). Subsequently, imports are subtracted and exports are added (elements k and l), resulting in local production according to commodity AV. Production is then transformed into sectors and intermediate consumption is subtracted, giving gross value added (AE). Gross value added is transformed from fixed to current prices (element n). Labour demand is determined by gross output and by labour demand coefficients (the inverse of productivity) at AE (element o).

Table 2. Groups of exogenous variables used in the decomposition analysis based on LINE.

a	Population size and composition, commuting (POP)
b	Income transfers (share of recipients in the population and average amount received (INCTRAN)
c	Tax rates (state, local authority) (TAXRATE)
d	Other income (unearned income) and deductions from gross income (OTHINC)
e	Intermediate consumption coefficients (INTCON)
f	Share of private consumption in disposable income (PCSH)
g	Composition of local private consumption (PCCOMP)
h	Tourist expenditure (TOUR)
i	Government consumption (GOVCON)
j	Investment (INVEST)
k	Imports from abroad (IMPORT)
l	Exports abroad (EXPORT)
m	Commodity taxes and trade margins (COMTAX)
n	Prices (PRICES)
o	Labour demand coefficients (LABCONT)

The decomposition method is completely flexible and can be undertaken for any variable within the model and for any range of years defined by the database. If the aggregations applied to the regional dimension are changed, for example through the use of municipalities and special sectors, decomposition can be used to break down results from a more aggregated level to a more detailed level. If the focus of the analysis is on earned rather than disposable income, then only the indirect and induced effects of variables such as income transfers and tax rates affect the outcome.

4 Concentration or dispersal of economic activity in Denmark? A decomposition analysis

4.1 Danish studies

Changes in the pattern of regional income growth have been the subject of a number of Danish studies, the focus of which has been twofold. One theme has been the process of *concentration or dispersal*, whereby changes in the volume of economic activity according to region are the subject of interest. The other theme relates to the problem of *convergence or divergence*, or the question of whether differences in per capita regional incomes increase or decrease.

A number of studies have provided evidence of regional per capita income convergence in Denmark during the 1980s and early 1990s (Dilling-Hansen and Smith, 1997; Dilling-Hansen et al, 1994; Ekspertudvalget, 1998; Groes, 1997; Indenrigsministeriet, 1997; Nordstrand et al, 2001). Convergence was related to strong economic growth in rural and semiperipheral West Jutland and Mid-Jutland. At the same time growth was slow in Greater Copenhagen (Jensen-Butler, 1992; Maskell, 1985). Other studies have examined the question of concentration or dispersal in the Danish economy (Indenrigsministeriet, 1997; Madsen and Rich, 1994; Madsen et al, 1992), and suggest a process of dispersal during this period. A number of studies referred to indicate that it may be possible to identify a reversal of these trends beginning around the early or mid-1990s, with respect both to convergence – divergence and to concentration – dispersal.

4.2 The results of the decomposition analysis

All six tables in this section have the same basic structure. The vertical axis shows labour market areas and the horizontal axis shows the fifteen groups of factors identified in section 3.3. The first column in each table shows the percentage change in regional income growth, measured in current prices, which can be compared with national income growth in the bottom row of column 1 [for example, table 3 (over) shows that earned income grew in Denmark by 31% in current prices in the period 1992 – 99]. The sum of the totals in columns 2 – 16 equals 31% (with rounding errors). Columns 2 – 16 show for each factor the corresponding regional deviation from the national change for that factor. For example, column 13 (exports) shows that the contribution to national growth in earned income arising from changes in exports is 7% (the column total). The relative impact of changes in exports for Greater Copenhagen is 1%, resulting in a total absolute impact in Greater Copenhagen of 8% (1% + 7%), which shows that changes in exports give an above average effect in Greater Copenhagen. Column 17 (TOTAL-REL) shows a similar way the relative regional contribution growth in earned income. Taking Greater Copenhagen again as an example, earned income grew by 33% (2% + 31%) in the period.

Table 3 shows the full results of one decomposition analysis, for growth in earned income at place of production for the period 1992 – 99. Table 4(a) (see over) shows the results of a similar analysis for the period 1980 – 92. In this table, in order to reduce the amount of information presented, six representative labour market regions have been chosen from table 3. The representative regions are Greater Copenhagen (metropolitan), Herning (West Jutland, with rapid rural industrialisation), Århus (Mid-Jutland, urban), Hjørring (North Jutland, peripheral), West and Mid-Lolland (very peripheral, with industries in decline), and Small Islands (typically very peripheral). Tables 4(b) and 4(c) show the results of a decomposition analysis of growth in earned income in services according to place of production in 1992 – 99 and 1980 – 92, respectively, again for the same selected regions. Table 5(a) (see over) shows the results of decomposition of growth in disposable income according to place of residence for the period 1992 – 99 and table 5(b) shows the results of a decomposition of growth in local authority tax revenues according to place of residence for 1992 – 99. Again, these tables use selected labour-market areas.

4.2.1 *Earned income at place of production*

Table 4(a) shows that in the period 1980 – 92 earned income grew markedly faster in the more peripheral West and Mid-Jutland areas than in Greater Copenhagen. This can be seen in the case of Herning (West Jutland) and Århus (Mid-Jutland), and it is also the case for other areas in West Jutland. Northern Jutland is a mixture, with

Table 3. Decomposition of growth in earned income by place of production from 1992 to 1999. Rows show labour market areas and columns show the fifteen groups of factors identified in section 3.3. The first column in each table shows the percentage change in regional income growth, measured in current prices, which can be compared with national income growth, in the bottom row of column one. The sum of the totals in columns 2 – 16 equals the column sum in column 1. Columns 2 – 16 show for each factor the corresponding regional deviation from the national change for that factor. Column 17 shows the deviation of the value for each area in column 1 from the total in column 1. For a description of column headings refer to table 2.

Labour market areas	(1) TOTAL	(2) POP	(3) INCTRAN	(4) TAXRATE	(5) OTHINC	(6) INTCON	(7) PCSH	(8) PCCOMP	(9) TOUR	(10) GOVCON	(11) INVEST	(12) IMPORT	(13) EXPORT	(14) COMTAX	(15) PRICES	(16) LABCONT	(17) TOTAL-REL
Greater Copenhagen	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02
Holbæk (Z)	0.31	0.00	0.01	0.00	0.00	0.01	0.00	−0.01	0.00	0.00	0.00	0.01	−0.02	0.00	0.01	0.00	0.00
Korsør (Z)	0.17	0.00	0.00	0.00	−0.01	0.02	0.00	−0.01	0.00	−0.01	−0.03	0.00	−0.09	0.00	−0.01	−0.02	−0.14
Nykøbing F (LF)	0.21	0.00	0.01	0.00	0.00	0.02	0.00	−0.01	0.00	0.00	−0.01	0.01	−0.09	0.00	−0.02	0.00	−0.10
Nætved (Z)	0.28	0.00	0.01	0.00	0.01	−0.03	0.00	−0.01	0.00	0.05	0.01	0.00	−0.10	0.00	0.03	0.01	−0.03
Bornholm	0.14	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	−0.02	−0.02	0.02	−0.07	0.00	−0.05	−0.01	−0.17
Odense (F)	0.27	0.00	0.01	0.00	0.00	−0.02	0.00	0.00	0.00	0.01	0.00	−0.01	−0.05	0.00	0.03	0.00	−0.04
Svendborg (F)	0.24	−0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	−0.02	−0.16	0.01	0.04	0.00	−0.07
Haderslev (SJ)	0.27	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	−0.01	0.01	−0.02	0.00	0.00	−0.03	0.00	−0.04
Sønderborg (SJ)	0.28	0.00	0.00	0.00	−0.01	−0.03	0.00	0.00	0.00	−0.02	−0.01	0.01	0.03	0.00	0.00	0.00	−0.03
Åbenrå (SJ)	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.03	−0.01	0.01	0.01	0.01	−0.02	0.00	−0.06
Esbjerg (WJ)	0.27	0.00	0.00	0.00	0.00	−0.01	0.00	0.00	0.00	−0.01	0.00	0.00	−0.01	0.00	−0.01	0.01	−0.04
Horsens (MJ)	0.35	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	−0.02	0.02	0.00	0.03	0.01	0.04
Kolding (MJ)	0.38	0.00	0.01	0.00	0.00	−0.01	0.00	0.00	0.00	0.00	0.02	−0.02	0.02	0.00	0.06	0.01	0.07
Vejle (MJ)	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	−0.01	0.04	0.00	−0.01	0.01	0.04
Herning (WJ)	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.02	0.01	−0.01	0.04	0.00	−0.01	0.01	−0.01
Holstebro (WJ)	0.33	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	−0.01	0.00	−0.01	0.04	0.00	−0.01	0.00	0.02
Randers (MJ)	0.29	0.00	0.01	0.00	0.00	−0.01	0.00	0.00	0.00	−0.01	0.00	−0.01	0.00	0.00	0.01	0.01	−0.02
Silkeborg (MJ)	0.34	0.00	0.01	0.00	0.01	−0.01	0.00	0.00	0.00	0.01	0.03	−0.01	−0.03	−0.01	0.03	0.01	0.02
Århus (MJ)	0.35	0.00	0.01	0.00	0.01	−0.01	0.01	0.00	0.00	0.03	0.03	0.00	−0.07	−0.01	0.05	0.02	0.04
Skive (WJ)	0.35	0.00	0.01	0.00	0.00	−0.10	0.00	0.00	−0.01	0.01	0.02	−0.02	0.07	0.00	0.05	0.02	0.04
Viborg (WJ)	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	−0.01	0.00	0.00	0.01	0.00	0.01
Frederikshavn (NJ)	0.19	0.00	0.00	0.00	−0.01	−0.01	0.00	0.00	−0.01	−0.02	−0.02	0.01	0.01	0.00	−0.06	−0.02	−0.12

Table 3 (continued).

Labour market areas	(1) TOTAL	(2) POP	(3) INCTRAN	(4) TAXRATE	(5) OTHINC	(6) INTCON	(7) PCSH	(8) PCCOMP	(9) TOUR	(10) GOVCON	(11) INVEST	(12) IMPORT	(13) EXPORT	(14) COMTAX	(15) PRICES	(16) LABCONT	(17) TOTAL-REL
Hjørring (NJ)	0.27	−0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.01	−0.01	−0.03	0.00	−0.03	0.00	−0.04
Ålborg (NJ)	0.35	0.00	0.01	0.00	0.01	−0.05	0.00	0.00	0.00	0.04	0.01	−0.01	−0.01	0.00	0.04	0.01	0.04
Other	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	0.00	0.01	−0.01	0.04	0.00	−0.02	0.00	−0.01
West and Mid-Lolland (LF)	0.10	−0.01	0.00	0.00	−0.01	−0.01	0.00	0.00	0.00	−0.04	−0.03	0.01	−0.06	0.01	−0.08	−0.01	−0.21
Small Islands	0.22	−0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	−0.02	−0.01	0.00	−0.03	0.00	−0.03	−0.01	−0.09
Outside regions	0.35	0.00	−0.01	0.00	−0.02	0.04	−0.01	0.00	0.00	−0.05	−0.04	0.03	0.11	0.01	−0.01	−0.03	0.04
Total	0.31	0.00	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.07	0.04	−0.03	0.07	−0.01	0.12	0.03	0.31

Z: Zealand; LF: Lolland-Falster; F: Fynen; SJ: South Jutland; MJ: Mid-Jutland; WJ: West Jutland; NJ: North Jutland.

Table 4. Decomposition of growth in earned income (a) according to place of production 1980 – 1992, (b) in service industries 1992 – 1999, and (c) in service industries 1980 – 1992. Rows show labour market areas and columns show the fifteen groups of factors identified in section 3.3. The first column in each table shows the percentage change in regional income growth, measured in current prices, which can be compared with national income growth, in the bottom row of column one. The sum of the totals in columns 2 – 16 equals the column sum in column 1. Columns 2 – 16 show for each factor the corresponding regional deviation from the national change for that factor. Column 17 shows the deviation of the value for each area in column 1 from the total in column 1. For a description of column headings refer to table 2.

Labour market areas	TOTAL	POP	INCTRAN	TAXRATE	OTHINC	INTCON	PCSH	PCCOMP	TOUR	GOVCON	INVEST	IMPORT	EXPORT	COMTAX	PRICES	LABCONT	TOTAL-REL
(a) *Earned income according to place of production, 1980 – 92*																	
Greater Copenhagen	1.22	−0.01	−0.02	0.00	0.00	0.00	0.00	0.00	−0.01	−0.01	0.00	0.01	−0.06	0.00	−0.01	−0.01	−0.10
Herning (WJ)	1.58	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	−0.01	0.14	0.01	0.09	0.01	0.26
Århus (MJ)	1.50	0.02	0.01	0.01	0.00	0.00	0.00	0.01	−0.01	0.02	0.00	0.00	0.00	0.01	0.07	0.02	0.18
Hjørring (NJ)	1.30	−0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	−0.02	0.00	0.02	0.01	−0.05	−0.01	−0.02
West and Mid-Lolland (LF)	0.93	−0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	−0.01	−0.01	−0.01	−0.06	0.00	−0.28	0.00	−0.39
Small Islands	1.23	−0.02	0.03	0.00	0.00	0.00	0.00	0.02	0.00	−0.01	−0.02	0.00	0.54	0.01	−0.71	0.08	−0.10
Total	1.32	0.04	0.05	0.02	0.00	0.00	0.01	0.01	0.01	0.03	0.01	−0.05	0.12	0.04	1.00	0.06	1.32
(b) *Earned income in services according to place of production, 1992 – 99*																	
Greater Copenhagen	0.37	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	−0.04	0.00	0.01	0.06	0.01	−0.03	−0.01	0.02
Herning (WJ)	0.40	0.00	0.00	0.00	0.00	0.02	0.00	−0.01	0.00	0.03	0.00	0.00	−0.02	0.00	0.02	0.03	0.05
Århus (MJ)	0.38	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.07	0.02	0.00	−0.12	−0.01	0.05	0.02	0.03
Hjørring (NJ)	0.30	−0.01	0.01	0.00	0.00	−0.02	0.00	−0.01	0.00	0.05	0.00	0.00	−0.12	0.00	0.05	0.00	−0.05
West and Mid-Lolland (LF)	0.19	−0.01	0.00	0.00	0.00	−0.05	0.00	−0.01	0.00	−0.03	−0.02	0.01	−0.07	0.02	−0.02	−0.01	−0.16
Small Islands	0.25	−0.01	0.00	0.00	0.00	−0.01	0.00	−0.01	0.00	−0.01	−0.01	0.01	−0.09	0.00	0.03	−0.01	−0.10
Total	0.35	0.00	0.01	0.00	0.02	0.01	0.01	−0.01	0.00	0.12	0.03	−0.01	0.03	−0.01	0.14	0.03	0.34
(c) *Earned income in services according to place of production, 1980 – 92*																	
Greater Copenhagen	1.42	0.00	−0.01	0.00	0.00	0.00	0.00	−0.01	0.00	−0.04	0.00	0.00	0.04	0.00	−0.07	−0.01	−0.11
Herning (WJ)	1.69	0.01	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.01	−0.07	0.02	0.07	0.03	0.14
Århus (MJ)	1.75	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.01	−0.01	−0.01	0.01	0.08	0.03	0.20
Hjørring (NJ)	1.73	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.09	0.00	0.00	−0.04	0.01	0.08	0.00	0.18
West and Mid-Lolland (LF)	1.37	−0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	−0.03	−0.01	0.01	−0.09	0.02	−0.09	0.00	−0.18
Small Islands	1.39	−0.02	0.03	0.00	0.00	0.00	0.00	0.03	0.01	−0.01	−0.01	0.01	1.08	0.02	−1.38	0.08	−0.14
Total	1.55	0.03	0.04	0.02	0.00	0.00	0.01	0.06	0.00	0.08	0.02	−0.02	0.05	0.01	1.21	0.06	1.55

LF: Lolland-Falster; MJ: Mid-Jutland; WJ: West Jutland; NJ: North Jutland.

Table 5. Decomposition of growth in (a) disposable income by place of residence 1992–99 and (b) local authority tax revenue 1992–1999. Rows show labour market areas and columns show the fifteen groups of factors identified in section 3.3. The first column in each table shows the percentage change in regional income growth, measured in current prices, which can be compared with national income growth, in the bottom row of column one. The sum of the totals in columns 2–16 equals the column sum in column 1. Columns 2–16 show for each factor the corresponding regional deviation from the national change for that factor. Column 17 shows the deviation of the value for each area in column from the total in column 1. For a description of column 1 headings refer to table 2.

Labour market areas	TOTAL	POP	INCTRAN	TAXRATE	OTHINC	INTCON	PCSH	PCCOMP	TOUR	GOVCON	INVEST	IMPORT	EXPORT	COMTAX	PRICES	LABCONT	TOTAL-REL
(a) *Disposable income by place of residence, 1992–99*																	
Greater Copenhagen	0.34	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	−0.01	−0.01	0.00	0.01	−0.01	0.01
Herning (WJ)	0.30	−0.01	−0.01	−0.02	−0.02	0.00	0.00	0.00	0.00	−0.01	−0.01	0.01	−0.04	−0.01	−0.01	0.10	−0.05
Århus (MJ)	0.37	0.03	−0.02	0.00	0.00	−0.01	0.00	0.00	0.00	−0.02	0.00	0.00	0.03	0.00	0.02	0.01	0.02
Hjørring (NJ)	0.29	−0.02	0.00	−0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.01	−0.01	0.02	−0.01	−0.02	−0.01	−0.06
West and Mid-Lolland (LF)	0.23	−0.02	0.00	−0.01	−0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	−0.03	0.01	−0.12
Small islands	0.23	−0.05	0.00	0.01	−0.02	0.01	0.00	0.00	0.00	0.02	0.01	−0.01	0.02	0.00	−0.03	−0.05	−0.12
Total	0.35	−0.01	0.07	0.01	0.09	−0.01	0.00	0.00	0.00	−0.02	−0.01	0.01	−0.02	0.00	0.09	0.13	0.35
(b) *Local authority tax revenue by place of residence, 1992–99*																	
Greater Copenhagen	0.42	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	−0.01	−0.01	0.00	−0.01	−0.03	0.00
Herning (WJ)	0.41	−0.02	−0.06	−0.01	0.00	0.00	−0.01	0.00	0.00	−0.01	−0.02	0.03	−0.08	0.00	−0.02	0.17	−0.01
Århus (MJ)	0.40	0.02	−0.03	−0.05	0.01	−0.02	−0.01	0.00	0.00	−0.02	−0.01	0.00	0.03	0.00	0.02	0.01	−0.02
Hjørring (NJ)	0.45	−0.04	−0.02	0.01	0.04	0.03	0.00	0.00	0.00	0.01	0.01	−0.01	0.03	0.00	−0.04	0.01	0.03
West and Mid-Lolland (LF)	0.33	−0.07	−0.03	−0.01	0.04	0.01	−0.01	0.01	0.01	0.00	0.00	0.00	−0.01	0.02	−0.07	0.03	−0.11
Small islands	0.44	−0.07	0.06	0.01	0.04	0.02	0.00	0.00	0.00	0.03	0.01	−0.02	0.02	0.00	−0.03	−0.06	0.02
Total	0.42	−0.02	0.14	0.00	−0.03	−0.02	0.00	0.00	0.00	−0.03	−0.01	0.01	−0.02	−0.01	0.18	0.23	0.42

LF: Lolland-Falster; MJ: Mid-Jutland; WJ: West Jutland; NJ: North Jutland.

Hjørring performing worse than the national average (though better than Greater Copenhagen) and other areas performing better than both. There was slow growth in West and Mid-Lolland, traditionally regarded as a very peripheral area. The Small Islands also fared badly.

Growth in earned income at place of production in the period 1992 – 99 (table 3) exhibits a change of pattern, Greater Copenhagen now has growth rates above the national average, whereas with few exceptions West and Mid-Jutland have growth rates around or just over the national average (such as Vejle, Holstebro, Silkeborg, Århus, Skive, and Viborg) or just under (including Herning, Esbjerg, and Randers). Income growth in Mid-Jutland and West Jutland, though in many areas remaining strong, is closer to the national average. Nonurban areas in North Jutland (Hjørring, Frederikshavn) have lower than average growth, and the poor performance of West and Mid-Lolland and the Small Islands is evident.

Thus, comparing the two periods, there does seem to be some evidence for a structural change in patterns of income growth. In the first period Greater Copenhagen experienced slow growth in earned income, which grew faster in the more peripheral and rural areas of Mid-Jutland and West Jutland, areas which had experienced rapid industrialisation. In this period the very peripheral regions of West and Mid-Lolland and the Small Islands performed badly. In the second period, growth in earned income in Greater Copenhagen was much stronger, well above the national average. Income growth in the regions of Mid-Jutland and West Jutland was still reasonably strong, though much closer to the national average and in some areas growth was below the national average. The very peripheral areas again performed badly in the second period.

The decomposition analysis permits identification of the factors lying behind these changes. In the period 1980 – 92 [table 4(a)] slow growth in Copenhagen was related to slow growth in exports, government consumption, and tourism, as well as very slow growth in population. In the second period, 1992 – 99, (table 3) there was a positive contribution to income growth in Copenhagen from export growth and a negative contribution from government consumption. The net result is growth above the national average. In the period 1980 – 92 growth in Herning (West Jutland) was driven by strong growth in exports, which is true for all of the new manufacturing areas of West Jutland. Price changes, and to a lesser extent changes in transfer incomes, also made a positive contribution in both Århus (Mid-Jutland) and Herning (West Jutland). Some of the provincial towns, such as Århus, gained through changes in government consumption.

In the second period, exports still played a positive, but reduced, role for the manufacturing areas of West Jutland and contributed negatively in the case of Århus. Relative price changes had a weak negative influence both in the manufacturing areas and in other areas of West Jutland (Herning), remaining marginally positive in Århus (Mid-Jutland). Government consumption contributed positively in general, and especially in Århus.

West and Mid-Lolland experienced in the first period a very negative contribution from exports and from price changes. In the period 1992 – 99 growth in exports and price changes continued to be the main determinants of below average growth. Slower growth for the Small Islands in this period was also related to these two factors.

In conclusion, the principal change in the pattern of income growth between the two periods was related to growth in exports and price changes. These were negative for Greater Copenhagen for 1980 – 92, becoming positive for 1992 – 99. The reverse was true for Århus (Mid-Jutland) and Herning (West Jutland), bringing these regions down to the national level during the second period. Most other areas were affected negatively by these two factors in the second period. West and Mid-Lolland, together with the Small Islands, experienced slow growth throughout the two periods.

4.2.2 *Earned income in private service at place of production*
Between 1980 and 1992 the general spatial pattern of growth in earned income in private service, shown in table 4(c), followed that of overall earned income in the period, described above. For example, growth was lower in Greater Copenhagen than the national average and in Herning (West Jutland) and Århus (Mid-Jutland) it was higher than the national average. In areas where the transport and tourism sectors were especially important, income growth was higher.

In the period 1992–99 [table 4(b)] the spatial pattern of growth in earned income in services followed that of earned income in general, with an improved performance in Copenhagen. Unlike in the first period, the better growth performance of areas with concentrations of both transport and tourism-related activity seems now to be absent. In general, there appears to be greater volatility in terms of changes in the spatial pattern of growth for earned income in services than is the case for overall earned income. Spatial differences in the growth in income in private service can be again explained primarily by growth in exports, changes in prices, and government consumption.

4.2.3 *Disposable income at place of residence*
The results obtained from a decomposition of income growth depend upon which type of income variable is examined. Differences between growth of earned income in general and growth of earned income in private service were noted above. To illustrate this point further, growth in disposable income has been examined. As described above, disposable income relates to place of residence not to place of production, and to households (an institution) not to sectors (activities).

In the period 1992–99, [table 5(a)] the variations in growth according to region follow the same general pattern as for earned income, but the deviations are, in general, smaller. This is to be expected because of the dampening effects of taxation and income transfers. These mechanisms are observable in the results of the decomposition analysis.

Greater Copenhagen had growth close to the national average, this growth was in part owing to a favourable growth in relative prices and in part to slow growth in exports. West and Mid-Lolland had below average growth in disposable income, but this deviation is much less than is the case for earned income. In these cases, population decline played an important and negative role together with the negative effect of changes in tax rates and other income. Population change and changes in tax rates had no effect on earned income, which can be compared with their negative effects on disposable income. Export growth and price changes have much smaller negative effects in these regions in comparison with their effects on earned income.

A number of regions in West and Mid-Jutland had growth rates in disposable income which lay above the national average, but these were lower than is the case for earned income. The main contributions to growth in this area were population growth and growth in other incomes; export growth and price changes contributed positively, but less so.

The peripheral regions in Jutland and the more peripheral regions of Fyn had below average growth rates, which are explained by population decline and variable contributions from income transfers, changes in tax rates, and other income. These factors had very little influence on changes in earned income.

A general conclusion is that an explanation of the pattern of change in disposable income involves factors related to place of residence. These factors include changes in population, tax rates, and income transfers, whereas changes in exports and prices, which are variables related to place of production, make a more limited contribution.

4.2.4 *Local authority tax revenue*

As is the case with disposable income, both households and local authorities have a direct interest in strong economic growth in the local area. However, changes in tax rates created opposite effects on disposable income compared with local authority revenues [table 5(b)]. The change in tax revenues for 1992–99 was close to the national average for Greater Copenhagen, markedly under the national average for West and Mid-Lolland, and around the national average for Århus (Mid-Jutland) and Herning (West Jutland), being under the national average in other more peripheral areas. In general, the regions with increasing local authority tax rates experienced, other things being equal, greater increases in tax revenues than in disposable income and vice versa.

5 Conclusion

An extended interregional and SAM-based model, which is a submodel within an interregional general equilibrium model for Danish regions, has been used as the theoretical foundation for a decomposition analysis of patterns of growth of regional income. The decomposition analysis has been applied to patterns of income growth according to region in Denmark in the last two decades of the last century.

The overall conclusion concerning changes in patterns of regional income growth and economic activity in Denmark since 1980 is that in the period 1980–92 there was clear regional dispersal of economic activity. After 1992 it appears that there has probably been a trend reversal in patterns of income growth, as there is evidence for a weak tendency towards concentration of economic activity, to the advantage of Greater Copenhagen, thereby suggesting a structural break. The 1980s were, interestingly, characterised by trends in regional economic growth that ran counter to sectoral trends at the national level (primarily growth in services), whereas in the 1990s the national trends of both growth in service sectors and export of services were more strongly reflected in regional growth trends, with higher growth rates in Copenhagen.

When growth in earned income according to place of production is decomposed, the main result is that variations in export growth and price changes are the main explanatory factors in both periods. Looking at disposable income according to place of residence, not only export growth and price changes are important, but changes in population, income transfers, tax rates, and other income also contribute to an explanation of variations in income growth. Growth in local government income tax revenues follows the general pattern of changes in disposable income, except that changes in tax rates have an opposite effect.

The principal theoretical and methodological conclusion is that the quality of the decomposition analysis depends fundamentally on the level of theoretical sophistication of the model used as its foundation. Furthermore, an extended model in structural form permits more powerful explanations to be developed using decomposition analysis than is the case with a reduced-form model. However, this requires either an analytical solution to the model, which transforms it from structural form to reduced form or alternatively decomposition based upon a structural-form model undertaken using numerical methods (in this case multiplier experiments using exogenous variables). These solutions ensure that problems do not arise from an interaction between endogenous and exogenous variables in a structural model. In the context of a simultaneous model, such as LINE, choice has been made with respect to the order of introduction of explanatory variables on the basis of the strength of association with the variable in question. The order in which the exogenous variables are introduced into the analysis is of importance in determining the contribution of each. One possible approach to determining this order is, if possible, to use a theoretical model involving a hierarchical structure of causality.

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Main Section B:

The General Interregional Model and LINE

Section 4:

The General Interregional Quantity Model

Bjarne Madsen

Section 4

The General Interregional Quantity Model

Bjarne Madsen

Abstract
Taking the Leontief and Miyazawa formulations of the interregional economic quantity model as the point of departure the general interregional static quantity model is developed. This model, which essentially is local rather than regional, incorporates a number of conceptual and theoretical changes, which have become necessary as economies become more diverse and differentiated. There is a need to integrate essentially subregional and local/urban activities covering such areas as commuting, shopping, tourism and trade into a general interregional modelling framework. The theoretical changes examined include a set of new geographical concepts and in the context of an interregional SAM the development of the two-by-two-by-two approach, involving two sets of actors (production units and institutional units), two types of markets (commodities and factors) and two locations (origin and destination). The equations of the general interregional quantity model are presented together with the solution of the model. Comparisons are made with the Danish interregional static CGE-model LINE and a typology of regions is proposed using the general model as a conceptual foundation.

Keywords: Interregional quantity models, Interregional SAM, Subregional models, Urban models, Regional typology.

1. Introduction[1]

As society becomes more differentiated and diverse it has been necessary to reflect these changes in the structure of regional and urban economic models. This increasing diversity has meant that our understanding of regional growth and development is more and more based on subregional spatial units and their interactions. This involves concepts such as urban, semi-rural and rural areas as well as labour market catchment areas and shopping hinterlands. New challenges have been created for regional and interregional modelling, where traditional approaches are less adequate for dealing with the new diversity. These new conditions have, for example, highlighted the necessity of incorporating such essentially subregional phenomena as commuting and shopping as well as trade in commodities at subregional and local levels into a more general regional and interregional modelling framework.

In this paper, the most important and necessary changes to established regional and interregional modelling theory and practice arising out of the new diversity are examined. Taking as a point of departure the institutional industry by industry regional and interregional input-output model a number of developments of this framework are first examined. I conclude that a further development of the theoretical framework is necessary in order to build models capable of dealing with the new realities. The extension of the theoretical framework involves a number of components. First, four geographical concepts are introduced into regional and interregional models. Second, these concepts are integrated with established social accounting matrix concepts. This leads to development of a two–by–two–by–two theoretical framework involving two actors (production units and institutional units), two markets (commodities and factors) and two locations (origin and destination).

[1] I want to thank Professor Chris Jensen-Butler for comments to earlier drafts of the article.

2. Geographical concepts in local models – conceptual lock-ins

Subregional components in subregional macroeconomic model necessitate the introduction of four geographical concepts: place of production, place of residence, place of commodity market and place of factor market. Mainstream single regional macroeconomic models are focused on place of production. There is limited or no treatment of place of residence or the market places being focussed on place of production. They also build on a division of productive activities by industry with limited differentiation between types of production factor, institutions and commodities. These features have the traditional input-output approach and the conceptual inertia of this approach constitutes a lock-in in terms of model developments. The approach has also had practical consequences for the way in which data have been constructed and collected, contributing significantly to inertia.

In the conventional interregional quantity-based input-output model, place of production and place of commodity market are included. In this sense this type of model can be regarded as a limited spatial model, as transfers between place of production and place of residence (commuting) and from place of residence to place of commodity market (shopping, tourism etc.) are not included.

Demo-economic models (Batey & Madden 1981, Madden & Batey 1983, Madden & Trigg 1990, Oosterhaven & Folmer 1985, Stelder & Oosterhaven 1995) represent a step forward, as they normally include a distinction between place of production and place of residence.

Land-use and transportation models employ some relevant spatial concepts, but they only reflect selected elements in the local economy and as such are partial models. For example, commuting models (Wang 2001, Renkow & Hoover 2001, Casado-Diaz 2000, Gitlesen & Thorsen 2002 and Artis et al. 2000), data and models use the concept of place of production (work) and place of residence, but these models do not include production and interregional trade. In shopping models (Lakshmanan & Hansen 1965, Guy 1996, Baker (2000, Cadwallader 1995) the concepts of place of residence and place of commodity markets are used, but they do not reflect the interregional structure in the determination of production and demand.

In single regional or non-spatial CGE models no spatial dimensions are included (Shoven & Whalley 1992). In the submodel for cost and prices corrections for the transformation of producer prices from place of production to place of commodity market are normally not included. In interregional CGE models (van den Bergh et al., 1996, Brocker 1995, 1998, 2002, Harrigan et al. 1991, McGregor et al. 1998, Haddad et al. 2002) spatial interaction is usually restricted to trade flows at a very aggregate level (typically two commodities). Commuting, shopping and tourist interaction are usually excluded.

3. Local and urban models based upon interregional input-output and SAM approaches

As a response to the issues described above, a new generation of local economic models is emerging, based upon further development of the traditional input-output approach and introducing new spatial concepts together with a disaggregated SAM (Round 1995, Kilkenny & Rose 1995, Hewings & Madden 1995a, 1995b).

Jun (1999) formulated an integrated metropolitan model, which captures intersectoral and interspatial relations as well as impacts on transport networks within a metropolitan area, including three components: multizonal input-output linkages, land-use forecast models and transport demand forecast models.

Hewings et al. (2001) set up a model for Chicago with 4 regions. Following Miyazawa's (1966, 1976) modelling approach economic interaction is first divided into indirect effects, driven by intermediate consumption and induced effects driven by private consumption. However, in the basic version, the model only includes a conventional interregional input-output model. There is no explicitly modelling of the effect of commuting which necessitates the introduction of a spatial division between place of production and place of residence. Likewise, the introduction of shopping would necessitate an economic link between place of residence and place of commodity market.

In the interregional CGE/SAM tradition Madsen & Jensen-Butler (2004) have constructed a local economic model for Denmark. The model consists of an interregional input-output model, includes and integrates models of trade, commuting, shopping and tourism. At the core of the model there is an interregional model for costs and prices and a link between the interregional quantity model and the interregional price model.

3.1 Extensions of the interregional quantity model

In the following a general interregional quantity model based upon the original interregional Leontief quantity model and developed using the two-by-two-by-two principle, described above, is presented.

3.1.1 The single region Leontief quantity model

The point of departure for our model construction is the Leontief quantity model, where gross output is determined by demand:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} \text{.................................}(1)$$

where

$\mathbf{x}$: gross output by sector
$\mathbf{A}$: intermediate consumption by sector of origin as share of gross output, by purchasing sector
$\mathbf{f}$: final demand, by sector

In this model it is assumed that gross output in a sector (x) is determined by intermediate consumption ($\mathbf{Ax}$) and final demand ($\mathbf{f}$) by sector. Using the equilibrium condition for the commodity market the analytical solution to the Leontief model is:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \text{..................................}(2\mathbf{a})$$
$$= (\mathbf{I} + \mathbf{A}^1 + \mathbf{A}^2 + \mathbf{A}^3 \text{......})\mathbf{f} \text{............}(2\mathbf{b})$$

Equation 2a shows that the solution of the Leonteif model can also be found using gross output by sector being equal to the product of the Leontief inverse and the vector of final demand. Equation 2b shows that the solution of the Leontief quantity model can be found sequentially using the power series approximation of the spillover and feedback effects between and within sectors. Each term expresses the effects of an extra round of intermediate consumption.

This model is a single region model as economic activities take place in one region without interaction with other regions. The model is based upon sectors (industries) and does not include explicit transformations from sectors to commodities (output) or transformations from commodities to sectors (input). The Leontief quantity model is therefore a reduced form model with underlying transformations, which appear when the model is applied to local and urban economies.

3.1.2 The interregional Leontief quantity model

Setting up an interregional quantity model involves extensions of the reduced form Leontief quantity model. The interregional quantity model includes intra- and interregional trade, which in spatial terms leads to a distinction between place of production and place of commodity market. The interregional quantity model establishes a link between place of commodity market, where intermediate consumption or final demand originates and place of production, where production takes place.

The Isard model (Isard 1951) is often described as the ideal interregional quantity model, which establishes a direct link between the intermediate consumption by purchasing sector in region S and gross output in the producing sector in region P. In the Isard model the A-matrix is simply extended, so that the same sector in two regions is defined as two different sectors. This in turn gives the same solution as in equation 2.

The Chenery-Moses model (Chenery 1953, Moses 1955) uses a pool approach, where intermediate consumption and final demand by region and sector are added together. Aggregate demand by sector enters into a demand pool. In simple models demand is met by production from other regions, which supply the pool. Both supply and demand are by sector. In more complex models a trade model establishes a link between economic activity at place of commodity market and at place of production. In some of the models it is simply assumed that supply is distributed amongst the supplying regions in proportion to the region's share of supply to the pool. In other approaches it is assumed that transport cost is an impediment to trade. Interregional trade can be modelled using a gravity model or an entropy maximising model.

However, both types of models involve the problem as they establish intra and interregional trade in sectors using a methodology which relies on the assumption that the make matrix for the region of demand can be used as the make matrix for the region of production. It seems more straightforward to use a commodity approach in trade assuming that demand by place of commodity market is transformed into commodity demand, then being transformed from place of commodity market to place of production still in commodity form and finally at the place of production being transformed from production in commodities to production in sectors (Greenstreet 1987).

Establishing a model with a spatial market for commodities also leads to inclusion of shopping for commodities for intermediate consumption. Assuming that intermediate consumption is determined at the place of production and that commodities for intermediate consumption are purchased at the place of the commodity market, the interregional quantity model can instead be written:

$$\mathbf{x} = \mathbf{DTS_{IC}B_{IC}b_{IC}} \circ \mathbf{x} + \mathbf{DTf} \quad \text{(3a)}$$
$$= \mathbf{DT}(\mathbf{S_{IC}B_{IC}b_{IC}} \circ \mathbf{x} + \mathbf{f}) \quad \text{(3b)}$$

where

$\mathbf{x}$: gross output by sector and by place of production

$\mathbf{D}$: the make matrix or gross output by commodity as share of gross output, by sector by place of production

$\mathbf{T}$: the intra- and interregional trade matrix or sales originating from place of production as share of total sales, by place of commodity market by commodity

$\mathbf{S_{IC}}$: the shopping matrix for intermediate consumption or intermediate consumption at the place of the commodity market as share of total intermediate consumption, by place of production by commodity

$\mathbf{B_{IC}}$: the use matrix or intermediate consumption by commodity as share of intermediate consumption by sector and by place of production

$\mathbf{b_{IC}}$: the intermediate consumption as share of gross output by sector and by place of production

$\mathbf{f}$: final demand by commodity and by the place of the commodity market.

The model now follows a real circle, which corresponds to reading from right to left in equation (3a). Starting with production at place of production ($\mathbf{x}$) in the first element of equation (3a) intermediate consumption by commodity is calculated employing an intermediate consumption share ($\mathbf{b_{IC}}$) and a use matrix ($\mathbf{B_{IC}}$). Moving again to the left, commodities for intermediate consumption are purchased at the place of the commodity market, which involves transport from place of production to place of commodity market ($\mathbf{S_{IC}}$, in effect a shopping model for intermediate consumption commodities). Moving again to the left the demand for commodities for intermediate consumption is transformed back to place of production using an intra- and interregional trade model ($\mathbf{T}$). Finally, gross output by sector and by place of production is calculated using a make matrix ($\mathbf{D}$). The second element in equation (3a) transforms final demand from place of commodity market to place of production using an intra- and interregional trade model ($\mathbf{T}$) and further from production in commodities to production by sector using a make matrix ($\mathbf{D}$).

Assuming that the interregional trade structure (T) and the make matrix (D) for intermediate and final consumption goods are identical, T and D can be set outside the parentheses (equation 3b).

Using the principle that supply equals demand the following analytical solution to the interregional Leontief quantity model can be derived:

$$\mathbf{x} = (\mathbf{I} - \mathbf{DTS_{IC}B_{IC}b_{IC}})^{-1}\mathbf{DTf} \text{..........} (4\mathbf{a})$$

$$= (\mathbf{I} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{1} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{2} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{3} + ...)\mathbf{DTf} \text{..........} (4\mathbf{b})$$

The power series expansion of the model (equation 4b) shows that the interregional quantity model can be solved numerically in a sequential procedure starting with exogenous final demand and then continuing with the first round effects, the second round effects etc.

This circle represents economic flows in the real economy, and solves a number of conceptual problems in the conventional interregional input-output model. First, the spatial division into place of production and place of commodity market is followed by a division of the SAM axis including both sectors and commodities, represented by the use and the make matrices. Second, the make matrix is now is defined for the region where production takes place. Finally, the introduction of a shopping matrix for intermediate consumption commodities reflects the fact that these commodities often are purchased at the location of the wholesaler, this being the place of the commodity market.

3.2 The Miyazawa single region quantity model

The next step in derivation of the general local/urban model is inclusion of interaction between production and institutional demand. This involves application of the Miyazawa quantity model (Miyazawa 1966 & 1976), which includes a transformation of income by sectors into income by institutions. In matrix notation the model is

$$\mathbf{x} = \mathbf{Ax} + \mathbf{CVx} + \mathbf{f} \text{..........} (5)$$

where

$\mathbf{C}$: Private consumption by sector as share of Gross Value Added (GVA), by type of institution

$\mathbf{V}$: GVA by type of institution as share of gross output, by sector

Following Miyazawa (1966 & 1976) this quantity model including the indirect effects (the A-matrix) and the induced effects (the V- and the C-matrix) can be solved in 3 ways:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A} - \mathbf{CV})^{-1}\mathbf{f} \text{...}(6\mathbf{a})$$

$$= \mathbf{B}(\mathbf{I} - \mathbf{CVB})^{-1}\mathbf{f} \text{...}(6\mathbf{b})$$

$$= \mathbf{B}(\mathbf{I} + \mathbf{CKVB})\mathbf{f} \text{...}(6\mathbf{c})$$

where

$$\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$$

$$\mathbf{K} = (\mathbf{I} - \mathbf{L})^{-1}$$

where

$$\mathbf{L} = \mathbf{VBC}$$

$$\mathbf{x} = (\mathbf{I} + (\mathbf{A} + \mathbf{CV})^{1} + (\mathbf{A} + \mathbf{CV})^{2} + (\mathbf{A} + \mathbf{CV})^{3} + ..)\mathbf{f} \text{......}(6\mathbf{d})$$

The first solution (equation 6a) is simply the direct solution, where the multiplier includes both the indirect effects (the A-matrix) and the induced effects (the product of the C and V matrices).

The second solution (equation 6b) separates the indirect effect multiplier matrix (the Leontief inverse), which in turn is multiplied by the induced effect multiplier matrix (the second bracket $(\mathbf{I} - \mathbf{CVB})^{-1}$).

The third solution (equation 6c) transforms the induced effect (the second bracket $(\mathbf{I} - \mathbf{CVB})^{-1}$) into a multiplicative expression starting with the traditional Leontief indirect effects multiplier matrix (B) multiplied by the GVA coefficient matrix (V), the interrelational income multiplier (K) and the consumption coefficient matrix (C). The interrelational income multiplier matrix shows the multiplier effect of the consumption of one institutional group on the income of another institutional group.

Finally, in equation (6d) the Miyazawa quantity model can be formulated as a sequential model using the power series expansion to expand the steps in the real circle with inclusion of the induced effects.

The Miyazawa extension of the Leontief quantity model includes the transformations from sectors to institutions and from institutions back to sectors. Miyazawa thereby changes the Leontief model from a one-dimensional model (sector by sector) into a model with transactions from sectors to institutions (V) and from institutions back to sectors (C).

3.2.1 The Miyazawa interregional quantity model

When used in a local or urban context, the spatial dimension must also be adjusted in such a way that production is located at the place of production whereas the institution is located at the place of residence of the institution. Private consumption is derived from demand originating at the place of residence and is purchased at the place of production. Introducing the real circle into the Miyazawa extended quantity model involves a geographical transformation in 2 steps: i) commuting, which transforms employment from place of production to place of residence (and from sectors to types of institutions); ii) combined shopping and trade, which transforms private consumption from place of residence to place of production (and from type of institution back to sector). Further, a kind of activity transformation in two steps is involved: from sectors to production factors and from production factors to commodeties. Transforming the interregional Leontief and the interregional Miyazawa quantity model into a local or an urban input-output model involves introduction of three spatial dimensions and three SAM dimensions into the modelling framework. In this section a local or urban model including these extensions is presented. In the following section the full extended four dimensional quantity model (using the two-by-two-by-two principle) is presented.

In this 3 dimensional version the quantity model includes the following spatial transformations:

- from place of production to place of residence corresponding to a transformation from sectors to type of production factors
- from place of residence to place of commodity market corresponding to a transformation from type of production factors to commodities
- from place of commodity market back to place of production corresponding to a transformation from commodities to sectors.

The model assumes that intermediate consumption and final demand are added before entering into the intra- and interregional trade system[2]. Gross output can now be expressed as follows:

$$\mathbf{x} = \mathbf{DTS_{IC}B_{IC}b_{IC}x} \qquad \textbf{(indirect effects)}$$

$$+\mathbf{DTS_{CP}B_{CP}b_{CP}} \circ \mathbf{pu_{CP}}^{-1} \circ \mathbf{pv} \circ \mathbf{v} \circ \mathbf{JGg} \circ \mathbf{x} \qquad \textbf{(inducedeffects)}$$

$$+\mathbf{DTf} \text{...}(7\mathbf{a}) \qquad \textbf{(direct effects)}$$

$$= \mathbf{DT(S_{IC}B_{IC}b_{IC}x + S_{CP}B_{CP}b_{CP}} \circ \mathbf{pu_{CP}}^{-1} \circ \mathbf{pv} \circ \mathbf{v} \circ \mathbf{JGg} \circ \mathbf{x} + \mathbf{f}) \text{......}(7\mathbf{b})$$

where

$\mathbf{S_{CP}}$: shopping for private consumption at the place of commodity market place as share of total demand, by commodity and by place of residence

$\mathbf{B_{CP}}$: the use matrix for private consumption or private consumption by commodity as share of private consumption, by place of residence.

$\mathbf{b_{CP}}$: the private consumption share or the private consumption as share of income, by place of residence.

$\mathbf{pu_{CP}}$ the prices on private consumption by type of production factors and by place of residence

pv the income rate index by type of production factors and by place of residence

[2] In principle, the model could be formulated with separate trade models for intermediate consumption and final demand. But because this information is not normally available and because problems with differences in trade patterns can be solved by further disaggregation of commodities, combining intermediate consumption and final demand as total demand at the place of commodity market is proposed.

v the income rate by type of production factors and by place of residence

J: Employment by place of residence as share of total employment, by type of production factors and by place of production (redefined, where type of production factor replaces type of institution)

G: transformation of employment from sectors (j) to type of production factors (g), by place of production

g Employment content of gross output, by sector and place of production.

From equation 7a it can be seen that the quantity model has two subcircles. The first represents the intermediate consumption or the indirect effects, whereas the second includes the private consumption (induced) effects. The third 'appendix' is the exogenous demand or the direct effects. Opposite to the Miyazawa model in the quantity model employment reflecting quantities – and not GVA – is derived from gross output using an employment content coefficient (g). Employment by type of production factor and by place of production (G) is determined before employment by place of residence using a commuting transformation matrix (J) is derived. At place of residence real income is determined on the basis of employment (q), the income rate (v), the income rate index (pv) and the prices on private consumption (pu_{CP}). Real income determining private consumption by commodity is determined on the basis of a private consumption share vector (b_{CP}) and a matrix for commodity composition of private consumption (B_{CP}).

The solution of the model is now straightforward:

$$x = (I - DTS_{IC}B_{IC}b_{IC} - DTS_{CP}B_{CP}b_{CP} \circ pu_{CP}{}^{-1}pv \circ v \circ JGg)^{-1} DTf \text{......}(8a)$$

$$\begin{aligned} &= (I + (DTS_{IC}B_{IC}b_{IC} - DTS_{CP}B_{CP}b_{CP} \circ pu_{CP}{}^{-1}pv \circ v \circ JGg)^{1} \\ &\quad + (DTS_{IC}B_{IC}b_{IC} - DTS_{CP}B_{CP}b_{CP} \circ pu_{CP}{}^{-1}pv \circ v \circ JGg)^{2} \\ &\quad + (DTS_{IC}B_{IC}b_{IC} - DTS_{CP}B_{CP}b_{CP} \circ pu_{CP}{}^{-1}pv \circ v \circ JGg)^{3} \\ &\quad \text{......}) DTf \text{...}(8b) \end{aligned}$$

The first solution (equation 8a) is simply the direct solution, where the multiplier includes both the indirect effects (the "$DTSB_{IC}$…" – or the indirect effects-subcircle) and the induced effects (the "$DTSB_{CP}$….Gg" – or the induced effects-subcircle). The second solution (equation 8b) transforms the solution into a sequential formulation using a power series expansion to expand the steps in the real circle with inclusion of the induced effects.

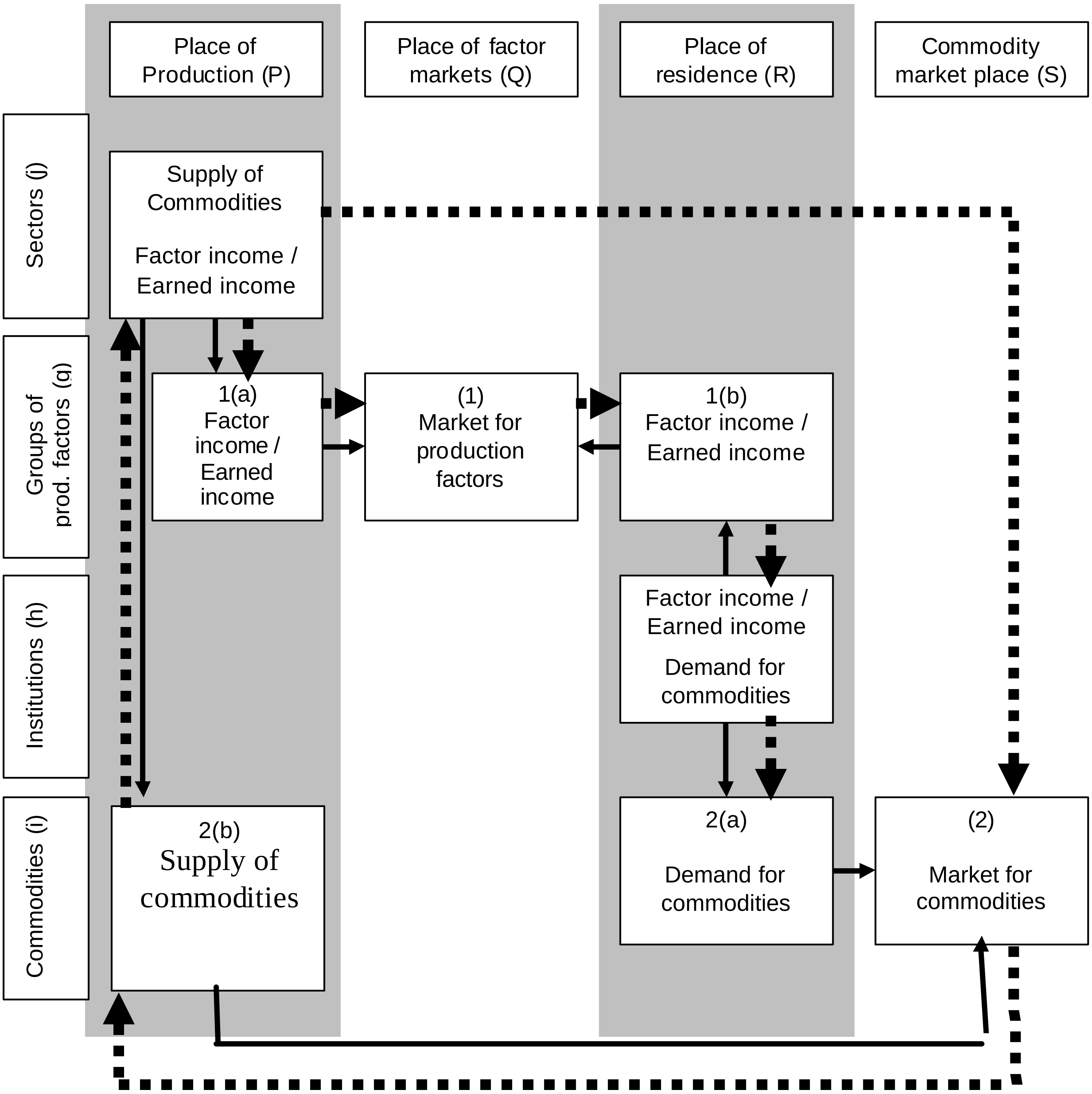
4. The general interregional quantity model

In section 3 the Leontief and Miyazawa interregional quantity models were presented and the two models were integrated and extended to derive a single model incorporating the fundamental spatial concepts identified above. To formulate the general interregional quantity model the two-by-two-by-two principle is used as the basic structure of the model of the local economy.

4.1 Basic concepts and dimensions in the general interregional quantity model – A graphical presentation[3]

There are three fundamental dimensions in the general quantity model, following the two-by-two-by-two principle. First, both producers and households are represented in the general quantity model. Second, two markets – the commodity market and the factor market – are included in the general model. Third, interaction between markets and actors includes information on origins and destinations. For both actors and markets basic geographical concepts have been used as well as social accounting concepts for activities. The model structure is presented in figure 1.

Figure 1. The conceptual basis of the general interregional quantity model



[3] In this paper only the real circle of the general model is presented. A similar structure applies in the dual model, which is the cost price circle in the general model

In comparison with the 3-dimensional model above, the factor market has been added, which involves a SAM dimension (groups of production factors) and a spatial concept (place of factor market). In factor markets supply and demand of production factors are to be found. Demand for production factors (g) is determined by production by sector (j) at the place of production (P). In figure 1 factor demand by sector is transformed into factor demand by type of production factor (g). On the supply side, supply of production factors by type of institution (h) is transformed into supply by type of production factor (g). Supply of a production factor is related to the place of residence of the institution (R). The factor market is geographically assigned to the market place for factors (Q).

Completing the presentation of the general model based on the two-by-two-by-two principle, in figure 1 in the commodity market there is a distinction between place of residence (R), the market place for commodities (S) and place of production (P). The market place for commodities links the demand for the commodity (from place of residence to the market place for commodities) to the supply of the commodity (from place of production to the market place for commodities). Before the transformation to the market place for commodities, the demand for commodities is transformed from institutional group (h) to commodity (i). On the supply side, production by sector (j) is transformed into production by commodity (i) and then supply is related geographically to the market place for commodities (S).

Second, in the general model both domestic and foreign sectors are represented in all markets. This involves not only international trade in commodities, but also other types of international interaction, such as cross-border commuting (income flows to and from abroad through commuting), border shopping, which includes one-day tourist expenditure in both directions, and tourism, again in both directions. This extension is included to make the general model more applicable as most regional systems do not encompass the world, but are surrounded by »the rest of the world«.

4.2 The model

In appendix 1 the equations of the general local/urban quantity model are presented. The model can be treated as a national model (the integrated Leontief and Miyazawa model), where a spatial dimension and a social accounting dimension have been included. The equations in the real circle are presented in structural form together with their partial solutions.

The equations follow the real circle as illustrated in figure 1. Starting in the upper left hand corner at place of production by sector (cell Pj) in equation 1 intermediate consumption $\mathbf{u}^{\mathbf{P,f}}_{\mathbf{j,IC}}$ is determined using an intermediate consumption share of gross output $b^{P,f}_{jIC}$. **u** is demand. The subscript IC indicates intermediate consumption by sector j. The superscript shows that intermediate consumption is determined at the place of production P and in fixed prices f. Intermediate consumption is a function of gross output $\mathbf{X}^{\mathbf{P,f}}_{\mathbf{j}}$ (by sector j, by place of production P in fixed prices f) and intermediate consumption's share of production $\mathbf{B}^{\mathbf{P}}_{\mathbf{j,IC}}$ (by sector j by place of production R in fixed prices f). In equations 2-6 intermediate consumption is determined in the following sequence:

- i) transformation from sectors to commodities (equation 2),
- ii) commodities for intermediate consumption purchased abroad are derived and subtracted (equation 3 and 4),
- iii) transformation from place of production to place of commodity market (equation 5) and
- iv) commodities for foreign intermediate consumption purchased at the place of the commodity market are added (equation 6).

The sequential structure of the equations of the real circle shown in appendix 1 is clear and follows the graphical presentation in figure 1. The real circle corresponds to a straight forward, but extended version of the Leontief and Miyazawa interregional quantity model and moves clockwise in figure 1. Continuing in the upper left corner (cell Pj), production generates employment using an employment content coefficient (equation 7). Employment is transformed from sectors j to factor groups g and includes employment hired from abroad (equations 8 to 10). Then employment is transformed from place of production P to place of factor market Q and further to the place of residence R through a commuting model (from cell Pg to cell Rg, going through the factor market, cell Qg, equations 10-11) and including employment abroad (equation 12). Employment together with exogenous income rates determines GVA, which in turn is the basis for determination of private consumption in market prices, by place of residence (cell Rg). First, GVA is transferred to groups of households (cell Rh), transformed from current prices to fixed prices and used in the determination of private consumption (equations 13-14).

The remaining equations 15-24 reflect the following overall path: Private consumption is divided into tourism (domestic and international) and local private consumption (cell Ri) and are assigned to the place of the commodity market (cell Si) using a shopping model for local private consumption. Private consumption, together with intermediate consumption, public consumption and investment constitute the total local demand for commodities (cell Si). Local demand is met by imports from other regions and abroad in addition to local production (cell Si). Through a trade model exports to other regions and production for the region itself are determined. Adding export abroad, gross output by commodity is determined (cell Pi). Through a reverse make matrix the cycle returns to production by sector (cell Pj).

4.3 The analytical solution to the general interregional quantity model

The model can now be solved by straightforward insertion. By inserting equation (24) into equation (25), and equation (23) into the modified equation (25) and so on, gross output by sector is a function of itself multiplied by two coefficient matrices, one of which reflects the indirect effects and the other the induced effects (see equation 1 in appendix 2). By using the Leontief and Miyazawa solution techniques, the following result is obtained:

$$x_j^{P,f} = \begin{bmatrix} I - D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{i,IC}^{P,S} (i - s_{i,IC}^{P,F}) \circ B_{IC,j,i}^{P} b_{j,IC}^{P} \\ - D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{i,CP}^{R,S} (i - b_{i,CP}^{R,F}) \circ B_{CP,h,i}^{R} b_{h,CP}^{R} \circ (pu_{h,CP}^{R})^{-1} \circ H_{g,h}^{R} \\ pv_g^{R,D} \circ v_g^{R,D} \circ J_g^{Q,R} J_g^{P,Q} (i - j_g^{P,F}) \circ G_{g,j}^{P} g_j^{P} \end{bmatrix}^{-1}$$

$$\begin{bmatrix} D_{i,j}^{P} z_i^{P,F} \\ + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ (u_{i,IC}^{S,F,f} + u_{i,CP}^{S,F,f} + u_{i,CO}^{S,f} + u_{i,IR}^{S,f}) \\ + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{i,CP}^{R,S} (i - b_{i,CP}^{R,F}) \circ B_{CP,h,i}^{R} b_{h,CP}^{R} \circ (pu_{h,CP}^{R})^{-1} \circ H_{g,h}^{R} pv_g^{R,F} \circ v_g^{R,F} \circ q_g^{R,F} \end{bmatrix} \ldots (9)\ or\ (A.2)$$

The solution includes a multiplier (the first 3 lines in the expression) and the exogenous demand in line 4-6. The multiplier can be decomposed into a line showing the indirect effects (line 1) and the induced effects (line 2-3). The exogenous demand can be divided into impacts from foreign exports (line 4), from commodities for intermediate consumption sold to abroad, foreign tourist consumption, governmental consumption and investment (line 5). And the impacts through income earned abroad from cross border commuting (line 6).

The analytical solution can be used to refine and document a) the multiplier effects of the economic activity in a local area on the local area itself and b) the spill-over effects from economic activities in other local areas on the local area. The general a priori result is that the multiplier becomes smaller the smaller the area, but also that the local area becomes increasingly dependent upon economic activity in other local areas, especially the neighbouring areas. The extreme example is of course the case where a local area only consists of one production unit. In this case the internal multiplier effect on demand from the production unit itself becomes small, whereas the economic dependency on economic activity in all other local areas becomes very important.

Another aspect is that the analytical solution shown in equation 9 is determined from the perspective of the place of production and industrial sector. If the subject was instead effects on income by place of residence (which is relevant from a place of residence and type of institution perspective), the impacts arising from changes in exogenous demand would be smaller. Alternatively, if the perspective was the effects on economic activity at the place of commodity market (such as retailing activities), then the impacts would be even smaller.

Using the analytical solution, a list of factors determining the level of production at the place of production can be drawn up, the sign in brackets showing the expected impacts on gross output of positive change in the factor:

- Intermediate consumption
  - Share of gross output (?)
  - Purchases abroad (-)
  - Purchases in other local areas (-)
  - Purchases from other local areas (+)
  - Purchases from abroad (+)
- Commuting
  - Place of residence abroad (-)
  - Place of residence in other local areas (-)
  - Place of production in other areas (+)
  - Place of production abroad (+)
- Local private consumption (shopping)
  - Propensity to consume (+)
  - Private consumption abroad, such as tourism abroad (-)
  - Shopping in other local areas, including domestic tourism (-)
  - Shopping from other local areas, including domestic tourism (+)
  - Private consumption from abroad, such as one-day tourism and conventional tourism (+)
- Trade
  - Import from abroad (-)
  - Import from other local areas (-)
  - Export to other local areas (+)
  - Export abroad (+)

As can be seen the above list includes factors which involve interaction between the local area itself, other regions and abroad. Other exogenous variables affecting the composition of demand

and supply in the commodity market and in the market for production factors also influence economic activity in the local area. Impacts of such changes should be modelled with other types of interregional models, which include impacts from changes in costs and prices.

The list can be used to identify different ideal types of local area. Each group is a pure type, whilst in reality a local area is a mix of different types. The definition relies upon the interaction balance, net

- areas based upon local production
  - primary products (trade balance and intermediate commodity-purchasing surplus in primary products)
  - secondary products (trade balance and intermediate commodity-purchasing surplus in secondary products)
  - advanced services (trade balance and intermediate commodity-purchasing surplus in tertiary products)
- residential areas
  - high level of outward commuting and low level of inward commuting
- areas based upon shopping
  - high level retailing services (local private consumption: shopping surplus)
  - conventional tourist areas (surplus in conventional tourist balance)
    - urban (surplus in conventional tourist balance)
    - rural (surplus in conventional tourist balance)
    - ecological (surplus in conventional tourist balance for ecological tourist type)
  - one day tourist areas
    - cultural (surplus in one-day tourist balance)
    - retailing (surplus in one-day tourist balance)

5. The LINE model and the general interregional quantity model

LINE is an interregional general equilibrium model constructed for Danish municipalities (Madsen et al. 2001, Madsen & Jensen-Butler 2004). The spatial *two-by-two-by-two* principle described above has been the guiding principle for the construction of the model and the interregional social accounting matrix, SAM-K (Madsen et al. 2001, Madsen & Jensen-Butler 2005), which serves as the database for LINE. Both LINE and SAM-K are designed on the basis of the structure shown in figure 1, using the double spatial entry principle or extended regional accounts (*two-by-two-by-two*), rather than non-spatial regional accounting principles (*two-by-two*).

The structure of LINE follows the basic interregional general equilibrium model shown in figure 1 with:

- Factor markets and commodity markets
- Demand and supply in both markets
- Origins and destinations in all interactions.

However, there are some differences between LINE and a model based upon a pure two-by-two-by-two principle. Some simplifications and some extensions are incorporated. The general model is adjusted in order to take into account the nature of the available data and the structure of the regional economy. In some respects the model is developed, whilst in other respects it is simplified.

First, the concept of the market place for factors does not correspond in general to reality. In practice, the place of residence of the production factor (such as labour) can be interpreted as both place of residence and the market place for factors. Only in very few cases does a geographically defined factor market exist. From a data collection point of view, only registration of place of residence and place of production in the factor market is possible. Therefore, the market place for factors has been excluded from LINE.

Second, only factor income from labour receives a full treatment. In Denmark, regional data on capital income only exist by place of production. Data on interregional commuting of capital income are still lacking, which makes a comparable treatment to commuting flows of labour income impossible and identification of a market place for capital income difficult to develop. In the present version of LINE capital income enters exogenously at the place of residence without any information on its spatial origin. Future developments with respect to savings and investments and identification of market places for these could include the use of pooling methods or identification of gross flows, referred to above.

Third, there is a need to keep track of economic interactions at the place of residence between factor groups and between institutions. Interaction between households and the governmental sector is important in order to describe the economic strength of households, for example measured by disposable income of households including income transfers from government and the subtraction of taxes. Interactions between factor groups, household and governmental sectors are therefore included in LINE.

Fourth, consumption by institutions (households) both from a decision-making or a behavioural point of view must be divided into two nested steps. First, at the place of residence consumption is determined at a high level of aggregation, for example food, clothing, transport etc. and in market prices. In the next step, at the place of commodity market the consumption bundles are further divided into specific commodities, transformed into basic prices, and distributed into domestic and foreign markets and among producing regions. From a decision-making point of view both the first and second steps are part of the household-decision problem, the sellers (the retailing sector) reflecting the demand from the households. The same is the case for intermediate consumption and for other types of final demand, such as governmental consumption and gross capital formation, where decisions are taken in two steps: First, at the place of residence deciding expenditure on aggregate commodity, such as expenditure on schools, and second in the institution at the place of commodity market and the place of production, where decisions on type of commodity, by domestic and foreign market and by supplying regions are taken.

Fifth, private consumption has been divided into local private consumption and domestic tourism. This division has been relevant in studies of tourism impacts, where in LINE it is possible to distinguish between tourism by foreigners, domestic tourism and tourism abroad, all divided into either one-day visits or visits involving overnight stays.

Sixth, different price concepts are included in the model, reflecting the fact that different variables for economic activity use different price concepts. For goods and services, total expenditures at the place of commodity market are measured in market prices. Supply of commodities entering the goods and services market is modelled in basic prices. Basic prices are defined as the value of production at the factory, not including net commodity taxes paid by the producer. Going from market/buyer prices to basic prices involves subtraction of commodity taxes and trade margins, where trade margins are also part of the commodity account. Interregional trade is measured in basic prices both seen from at the place of production and place of commodity market point of view. At the place of commodity market commodity prices are transformed from basic prices to market prices.

Finally, LINE is based upon two interrelated circles: a real circuit described above and a dual cost-price circuit. Figure 1 shows the general model structure, based upon the real circle employed in LINE. The two circles are linked together with a link from real economic activities to formation of cost and prices (mainly a weighting system for determining costs and prices) and from the costs and prices to real economic activity. This last link includes the effects of cost and price changes on demand, the transformation of disposable income in current prices to fixed prices and the effects on export and import prices in turn determining exports and imports. Part of the model uses fixed prices (the demand and supply of commodities) and part of the model uses current prices (earned income, taxes, transfer incomes and disposable income).

Here, only a brief comparison of LINE and the general interregional quantity model is made. The full LINE model and its equations are described in Madsen et al. (2001) and Madsen & Jensen-Butler (2004). LINE has been constructed as a flexible model on a number of key dimensions. For any application of LINE the model and the associated database are aggregated in order to capture the special requirements of each case. Thus, in any version of LINE the model configuration is specific. One example of such an application is provided by Madsen & Jensen-Butler (2004), where the following dimensions were used:

Sectors
21 sectors aggregated from the 133 sectors used in the national accounts.

Factors
7 age, 2 gender and 5 education groups.

Households
4 types, based upon household composition.

Needs
For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.

Commodities
27 commodities, aggregated from 131 commodities used in the national accounts.

Regions
277 municipalities, including one state-owned island and one unit for extra-regional activities, this being the lowest level of spatial disaggregation. Regions are defined either as place of production, place of residence or as place of commodity market. In this version of LINE the (277) municipalities have been aggregated into 16 regional units, including one unit for extra-regional activities.

6. Summary

In this paper the general interregional static quantity model for local or urban economies has been presented. The model represents an extension and integration of the interregional Leontief quantity model including the indirect effects and the interregional Miyazawa quantity model including the induced effects. The general interregional quantity model is based upon the two-by-two-by-two principle including a) markets for commodities and factors, b) production units and institutional units and c) origin and destination for the demand and supply in the two markets. The general interregional quantity model includes a foreign sector and the analytical solution to the model is presented. The basic structure embedded in the general interregional quantity model was used to identify a new typology for local areas according to their specialisation in the intra and interregional interaction. The general interregional quantity model is compared with LINE, which is a local economic model for Danish regions with a structure similar to the structure of the general interregional and local quantity model. Differences reflecting data limitations and the need to include interaction between households and governmental sector and including a distinction between market prices and basic prices are examples of the deviations between the idealised general interregional quantity model and operationalised models.

Appendix 1

The equations for the general interregional quantity model for local and urban economies in structural form

Variables in the quantity model
The variables in the general interregional quantity model are denoted in the following way:

Variables

x:	Gross output
D:	Make coefficient matrix
q:	Employment
T:	Trade coefficient matrix
b:	Use coefficient vector of demand
z:	Trade vector
B:	Use coefficient matrix of demand
pu:	Price index vector for demand
G, H, J:	Employment transformation coefficient matrices
pv:	Income index vector
v:	Income rate
h:	Income vectors

Superscripts

P:	Place of production (regional axes)
Q:	Place of factor market (regional axes)
R:	Place of residence (regional axes)
S:	Place of commodity market (regional axes)
D:	Domestic
F:	Rest of the world
f:	Fixed prices

Subscripts
SAM-axes

j:	Sector (SAM-axis)
g:	Groups of factors (SAM axes)
h:	Type of institution (SAM axis)
i:	Commodity (SAM axis)
IC:	Intermediate consumption
CP:	Private consumption
CO:	Governmental consumption
IR:	Investments

The equations in structural form

$u_{IC,j}^{P,f} = b_{IC,j}^{P} \circ x_{j}^{P,f}$ ....(1)

$u_{IC,i}^{P,f} = B_{IC,j,i}^{P} u_{IC,j}^{P,f}$..(2) *from Pj to Pi*

$u_{IC,i}^{P,F,f} = b_{IC,i}^{P,F} \circ U_{IC,i}^{P,f}$ ....(3)

$u_{IC,i}^{P,D,f} = u_{IC,i}^{P,f} - u_{IC,i}^{P,F,f}$ ....(4)

$u_{IC,i}^{S,D,f} = S_{IC,i}^{P,S,D} u_{IC,i}^{P,D,f}$ ....(5) *from Pi to Si*

$u_{IC,i}^{S,f} = u_{IC,i}^{S,D,f} + u_{IC,i}^{S,F,f}$ ....(6)

$q_{j}^{P} = g_{j}^{P} \circ x_{j}^{P,f}$ ....(7)

$q_{g}^{P} = G_{g,j}^{P} \circ q_{j}^{P}$ ....(8) *from Pj to Pg*

$q_{g}^{P,F} = J_{g}^{P,F} \circ q_{g}^{P}$ ....(9)

$q_{g}^{P,D} = q_{g}^{P} - q_{g}^{P,F}$ ....(10)

$q_{g}^{Q,D} = J_{g}^{P,Q} q_{g}^{P,D}$ ....(11) *from Pg to Qg*

$q_{g}^{R,D} = J_{g}^{Q,R} q_{g}^{Q,D}$ ....(12) *from Qg to Rg*

$h_{g}^{R} = pv_{g}^{R,D} \circ v_{g}^{R,D} \circ q_{g}^{R,D} + pv_{g}^{R,F} \circ v_{g}^{R,F} \circ q_{g}^{R,F}$ ....(13)

$h_{h}^{R} = H_{g,h}^{R} h_{g}^{R}$..(14) *from Rg to Rh*

$u_{CP,h}^{R,f} = b_{CP,h}^{R} \circ pu_{CP,h}^{R}{}^{-1} \circ h_{h}^{R}$ ....(15)

$u_{CP,i}^{R,f} = B_{CP,h,i}^{R} u_{CP,h}^{R,f}$...(16) *from Th to Ti*

$u_{CP,i}^{R,F,f} = b_{CP,i}^{R,F,f} \circ u_{CP,i}^{R,f}$...(17)

$u_{CP,i}^{R,D,f} = u_{CP,h}^{R,f} - u_{CP,h}^{R,F,f}$ ....(18)

$u_{CP,i}^{S,D,f} = S_{CP,i}^{R,S} u_{CP,i}^{R,D,f}$ ....(19) *from Ti to Si*

$u_{i}^{S,f} = u_{CP,i}^{S,D,f} + u_{CP,i}^{S,F,f}$ ....(20)

$u_{i}^{S,f} = u_{IC,i}^{S,f} + u_{CP,i}^{S,f} + u_{CO,i}^{S,f} + u_{IR,i}^{S,f}$...............................(21)

$z_{i}^{S,D,f} = (i - d_{i}^{S,F}) \circ u_{i}^{S,f}$ ....(22)

$z_{i}^{P,D,f} = T_{i}^{S,P} z_{i}^{S,D,f}$ ....(23) *from Si to Pi*

$x_{i}^{P,f} = z_{i}^{P,D,f} + z_{i}^{P,F,f}$ ....(24)

$x_{j}^{P} = D_{i,j}^{P} x_{i}^{P,f}$ ....(25) *from Pi to Pj*

Appendix 2

The analytical solution for the general interregional quantity model for local and urban economies

The model in reduced form

$$
\begin{aligned}
x_j^{P,f} = {} & D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{IC,i}^{P,S} (i - s_{IC,i}^{P,F}) \circ B_{IC,j,i}^{P} b_{IC,j}^{P} \circ x_j^{P,f} \\
& + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{CP,i}^{R,S} (i - b_{CP,i}^{R,F}) \circ B_{CP,h,i}^{R} b_{CP,h}^{R} \circ (pu_{CP,h}^{R})^{-1} \circ H_{g,h}^{R} \\
& \quad pv_g^{R,D} \circ v_g^{R,D} \circ J_g^{Q,R} J_g^{P,Q} (i - j_g^{P,F}) \circ G_{g,j}^{P} g_j^{P} \circ x_j^{P,f} \\
& + D_{i,j}^{P} z_i^{P,F,f} \\
& + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ (u_{IC,i}^{S,F,f} + u_{CP,i}^{S,F,f} + u_{CO,i}^{S,f} + u_{IR,i}^{S,f}) \\
& + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{CP,i}^{R,S} (i - b_{CP,i}^{R,F}) \circ B_{CP,h,i}^{R} b_{CP,h}^{R} \circ (pu_{CP,h}^{R})^{-1} \circ H_{g,h}^{R} pv_g^{R,F} \circ v_g^{R,F} \circ q_g^{R,F} \quad \text{....(1)}
\end{aligned}
$$

The solution to the model

$$
x_j^{P,f} = \begin{bmatrix} I - D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{IC,i}^{P,S} (i - s_{IC,i}^{P,F}) \circ B_{IC,j,i}^{P} b_{IC,j}^{P} \\ - D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{CP,i}^{R,S} (i - b_{CP,i}^{R,F}) \circ B_{CP,h,i}^{R} b_{CP,h}^{R} \circ (pu_{CP,h}^{R})^{-1} \circ H_{g,h}^{R} \\ pv_g^{R,D} \circ v_g^{R,D} \circ J_g^{Q,R} J_g^{P,Q} (i - j_g^{P,F}) \circ G_{g,j}^{P} g_j^{P} \end{bmatrix}^{-1}
$$

$$
\begin{bmatrix} D_{i,j}^{P} z_i^{P,F} \\ + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ (u_{IC,i}^{S,F,f} + u_{CP,i}^{S,F,f} + u_{CO,i}^{S,f} + u_{IR,i}^{S,f}) \\ + D_{i,j}^{P} T_i^{S,P} (i - d_i^{S,F}) \circ S_{CP,i}^{R,S} (i - b_{CP,i}^{R,F}) \circ B_{CP,h,i}^{R} b_{CP,h}^{R} \circ (pu_{CP,h}^{R})^{-1} \circ H_{g,h}^{R} pv_g^{R,F} \circ v_g^{R,F} \circ q_g^{R,F} \end{bmatrix} \text{......(2)}
$$

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Section 5:

The General Interregional Price Model

Bjarne Madsen

Section 5

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Bjarne Madsen

Abstract

In the input-output tradition regional economic activity is are related to changes in exogenous real demand, including interregional spill-over and feedback effects. However, the effects of exogenous changes in costs and prices on real economic activity have usually been neglected, despite the fact that the redistributive effects from this dual element in the intra- and interregional economy can be considerable and can have effects on economic activity which are comparable with the quantity effects.

CGE models, on the other hand, have explicitly addressed this issue using non-linear functions to overcome theoretical problems related to the use of fixed coefficients, permitting for example a more satisfactory treatment of substitution between factors of production or commodities as well as the effects of changing costs on patterns of trade and other forms of interaction.

Following the input-output tradition, a static structural model for the formation of prices in a local economy, the static general interregional price model, involving price determination through local economic interaction such as commuting, shopping and interregional trade, is derived. The equations of the static general interregional price model are presented together with the solution of the model. The theoretical changes examined include a set of new geographical concepts and in the context of an interregional SAM the development of the two-by-two-by-two approach, which involves two sets of actors (production units and institutional units), two types of markets (commodities and factors) and two locations (origins and destinations).

Finally, a simultaneous solution to the combined static general interregional quantity and price model based upon the most simple link between the two is outlined.

1. Introduction

Two different general approaches to regional and interregional modelling can be identified: the Keynesian input-output tradition, which is fundamentally a linear approach and the more recent CGE tradition involving models of a more flexible form and non-linear relationships. In the input-output tradition regional and interregional spillover and feedback effects are almost exclusively related to changes in the real economic activities. Construction of the static general quantity model is presented in Madsen (2007) However, the effects of changes in costs and prices on real economic activity have usually been neglected, despite the fact that the redistributive effects from this dual element in the intra- and interregional economy can be considerable and have effects on economic activity, which are comparable with the quantity effects.

CGE models on the other hand have explicitly addressed this issue using non-linear functions to overcome theoretical problems related to the use of fixed coefficients, permitting for example a more satisfactory treatment of substitution between factors of production or commodities as well as the effects of changing costs on patterns of trade and other forms of interaction. Although CGE models include substitution effects arising from changes in relative prices, determining changes in patterns of demand, CGE models do not generally include a full description of the cost and price determination both in spatial and SAM terms. In general, CGE models do not provide a full description of the operation of the local economy. Furthermore, modelling the complexity of local interregional economy in a CGE framework rapidly leads to problems of derivation of analytical solutions and even when using numerical solution there are problems of mathematical intractability, multiple equilibria and failure to converge on a solution. In addition to these issues, the benefits of the CGE approach are often unclear except perhaps for their anchorage to micro-economic theoretical foundations.

These concerns lead to renewed interests in developing models based upon the classical input-output price model. The basic elements in this approach are as follows:

The general static interregional price model, which is developed below, is the dual of the general interregional quantity model (Madsen 2007). Price formation is therefore directly linked to the structure of the production and consumption determined in the general interregional quantity model, which involves the application of a set of new geographical concepts together with established SAM concepts. The core is development of the two-by-two-by-two approach, which involves two sets of actors (production units and institutional units), two types of markets (commodities and factors) and two locations (origins and destinations).

Costs and prices in the local economy

In this paper the focus of interest concerns modelling of the redistribution in costs and prices. The redistribution can have both a SAM dimension and a regional dimension or a combination of both. From a regional and local perspective, cost and price changes are passed through the system of intra- and interregional trade, shopping and tourism as well as the interregional system of commuting. From a SAM perspective cost and price changes are passed on from one actor to another. For example, cost and price changes in production are passed on to final consumers, which affects their real income, which in turn affects level of income through labour-market adjustments changing the costs in production.

Direct cost and price changes are transferred to the end user. The process of transfer represents, assuming a constant level of real economic activity, a pure redistribution to the end user of the direct cost and price changes. However, the total effects of these transfers generate both direct and derived effects in the real economy.

In this paper the general static interregional model for costs and prices is examined. The main focus of this chapter is on the spillover and feedback effects in the cost price system, where the model describes the process of full or partial transfer of cost and price changes. The point of departure for the interregional cost and price model is the Leontief price model, which is extended in order to set up a general model for cost and price formation in the local economy. It also includes the dual cost and price version of the interregional Miyazawa model (Miyazawa 1966, 1976). Finally, an analytical solution for the general static interregional price model is derived.

Assuming that the total effects of the cost and price changes can be identified, the effects on the real economy can then be evaluated using the general static interregional quantity model. Exogenous demand in the quantity model depends on the relative prices, which are derived from the price model. Structural coefficients, such as those determining the composition of demand for commodities and the structure of spatial interaction are also derived from relative prices. A simple link between the quantity and price models related to foreign export is presented and an analytical model for the combined model is derived.

Finally, an interregional cost and price model is part of the LINE model. LINE is a local economic model for the Danish spatial economy, and differences in relation to the general interregional price model are identified.

2. Modelling costs and prices in the interregional economy

For models which describe the process of transfer of cost and price changes it is normally assumed that these changes are passed on in full, reflecting perfect competition assumptions.

Given the level of real economic activity, changes in costs and prices in this type of model follow an adding-on principle, where changes in cost or prices are passed to the next step in the production-demand chain, which in turn are passed to the next step ending as an add-on to the price for the end user. End users usually include households at home and abroad. However, who constitutes an end user depends on the type of model.

The Leontief price model is based on this principle of passing on in full changes in costs and prices. The standard Leontief price model is presented in Miller and Blair (1985) and Bulmer-Thomas (1982). At the national and international level there are a number of studies using the Leontief price model (Polenske 1978, Moses 1974). The Leontief price model has been included in a number of macro-economic models at the national level (for example in the Danish case ADAM (Dam 1995)) and at the international level (for example the GTAP model (Bach et al 2000)) to model changes in cost and prices.

However, at the regional level, studies or even models of the process of price determination are rare. Oosterhaven (1981) extends the national price model to an interregional price model, including price relations operating through intermediate consumption. In a specific model the impacts on prices from changes in consumer prices operating through changes in factor payments and producers prices are examined. The model was used in a study of the regional impacts of the 1970-1975 price increases for raw materials and crude oil. Toyomane (1986) developed an interregional Leontief price model including indirect effects through intermediate consumption. The model formulated in an Isard IRIO (Isard 1951) and Chenery-Moses (Chenery 1953, Moses 1955) pool approach was used for evaluation of the impact of transport system changes. Dietzenbacher (1997) reformulated the Ghosh (1958) supply driven model as the dual to the Leontief quantity model, the standard Leontief price model. However, this was not done in the context of an interregional model.

3. Interregional price models

3.1 The interregional Leontief price model

The point of departure is the price model of the Leontief system. In matrix notation the price model is

$$\mathbf{p}' = \mathbf{p}'\mathbf{A} + \mathbf{v}' \circ (\mathbf{i}' - \mathbf{b}_{\mathbf{IC}}') \quad (1)$$

where

$\mathbf{p}'$: Price index by sector (row vector)

$\mathbf{A}$: The matrix of direct input coefficients

$\mathbf{v}'$: GVA cost index by sector

$\mathbf{i}$: Unity vector

$\mathbf{b}_{\mathbf{IC}}'$: Intermediate consumption as share of gross quantity by sector

$'$: Transposition

$\circ$: Element by element multiplication

Like the Leontief quantity model the Leontief price model can be solved

$$\mathbf{p}' = \mathbf{v}' \circ (\mathbf{i}' - \mathbf{b}_{\mathbf{IC}}')(\mathbf{I} - \mathbf{A})^{-1} \quad (2\mathbf{a})$$

$$= \mathbf{v}' \circ (\mathbf{i}' - \mathbf{b}_{\mathbf{IC}}')(\mathbf{I} + \mathbf{A}^1 + \mathbf{A}^2 + \mathbf{A}^3 + \dots) \quad (2\mathbf{b})$$

As can be seen, initially the price model looks similar to the Leontief quantity model. However, important differences should be noted: First, the sector price vector $\mathbf{p}'$, the GVA share vector $(\mathbf{i}'-\mathbf{b_{IC}}')$ and cost index vector $\mathbf{v}'$ are row vectors, whereas the gross quantity and final demand vectors in the Leontief quantity model are column vectors. Second, the cost index vector in the Leontief price model is pre-multiplied, whereas the column vector in the Leontief quantity model is post-multiplied. Finally, the cost index vector contains indices, whereas in the Leontief quantity model final demand and quantity vectors contain values. These differences lead to different interpretations of the analytical solutions and the multipliers.

The A-matrix and the resulting multiplier matrix $(\mathbf{I}-\mathbf{A})^{-1}$ in the Leontief quantity and Leontief price models are the same. In the Leontief quantity model the exogenous final demand column vector is post-multiplied by the Leontief inverse, showing the total direct and indirect effects on gross quantity of final demand. The sectoral quantity multiplier is the sum of the values in any column in the Leontief inverse. In the Leontief price model the exogenous GVA cost index row vector is pre-multiplied by the Leontief inverse and gives the total impacts on sector prices of changes in the exogenous GVA cost index. Here, the sectoral price index is the sum of the values in any row in the Leontief inverse.

3.2 The interregional Leontief price model

The one region Leontief price model can be transformed into an interregional price model. In Oosterhaven (1981) the interregional Leontief price model has been formulated as the dual price model of the Isard IRIO model (Isard 1951). In the IRIO model equations 1 and 2 apply directly interpreting different sectors as sector by region. In Toyomane (1986) the interregional price model has been formulated as both the dual price to the Isard IRIO model and as the dual model to the MRIO quantity model (Chenery 1953, Moses 1955) building on the pool method.

In the formulation of the interregional Leontief price model, Oosterhaven and Toyomane assume as in the case of the Isard and the MRIO quantity models, that the make matrix of the demanding region rather than the producing region enters into the interregional price model.

Assuming instead that the make matrix of the supplying region enters into the price model and that intra and interregional trade is defined in commodities rather than in sectors the price model can be formulated in a more satisfactory way. Taking the formulation of Greenstreet (1987) as the point of departure, the price model can now be reformulated:

$$\mathbf{p}'=\mathbf{p}'\mathbf{D}\mathbf{T}\mathbf{S_{IC}}\mathbf{B_{IC}}\mathbf{b_{IC}}+\mathbf{v}'\circ(\mathbf{i}'-\mathbf{b_{IC}}') \quad \text{................................(3)}$$

where:

- $\mathbf{D}$: The make matrix (gross quantity by commodity as share of gross quantity, by sector by place of production).
- $\mathbf{T}$: The intra and interregional trade matrix (sales originating from place of production as share of total sales, by place of commodity market by commodity).
- $\mathbf{S_{IC}}$: The shopping matrix in intermediate consumption (intermediate consumption at the place of commodity market as share of total intermediate consumption, by place of production by commodity).
- $\mathbf{B_{IC}}$: The use matrix (intermediate consumption by commodity as share of intermediate consumption, by sector by place of production).
- $\mathbf{b_{IC}}$: The intermediate consumption share (intermediate consumption as share of gross output, by sector by place of production).

The cost and price effects follow a sequential structure similar, but in the opposite direction to that in the interregional Leontief quantity-model. Starting at the place of production, the intermediate consumption price index ($\mathbf{p}'$) together with the GVA cost index ($\mathbf{v}'$) determine commodity prices at the place of production, by sector. This price index is then transformed into a price index for commodities using the make matrix ($\mathbf{D}$), all at the place of production. The commodity price index is in turn transformed from place of production into place of commodity market using the matrix for intra and interregional trade ($\mathbf{T}$). Using the matrix for shopping for intermediate commodities ($\mathbf{S_{IC}}$) transforms the commodity price index from place of commodity market into place of production. Finally, the price index is transformed from commodities back to sectors using the intermediate consumption use matrix ($\mathbf{B_{IC}}$) and the intermediate consumption share ($\mathbf{b_{IC}}$).

Solving the interregional price model gives the following

$$\mathbf{p}' = \mathbf{v}' \circ (\mathbf{i}' - \mathbf{b_{IC}}')(\mathbf{I} - \mathbf{DTS_{IC}B_{IC}b_{IC}})^{-1} \text{.....................} (4\mathbf{a})$$

$$= \mathbf{v}' \circ (\mathbf{i}' - \mathbf{b_{IC}}') \cdot (\mathbf{I} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{1} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{2} + (\mathbf{DTS_{IC}B_{IC}b_{IC}})^{3} + ...) \text{.........} (4\mathbf{b})$$

This power series expansion of the analytical solution to the interregional price model gives the sequential structure of not only the model, but also of the numerical solution routine, which can be denoted the cost-price circle: First, the direct effects on prices of changes in the gross GVA cost deflator are calculated ($\mathbf{v}' \circ (\mathbf{i}' - \mathbf{b_{IC}}')$), then the first round effects from the price transformations are calculated, starting with prices of production at the place of production by sector and repeating the sequential calculation of price transformations as described above in equation 4b.

3.3 The interregional Leontief and Miyazawa price model

The price changes not only have impacts on sector prices through intermediate consumption, but also on the prices of private consumption. Assuming that changes in consumer prices are transferred to income, this in turn will have an impact on the cost of production. This effect can be seen as the dual to the Miyazawa extended quantity model. In the following the integrated model, including the interregional price model for price effects operating through the intermediate consumption system (see above) and the dual price model of the Miyazawa real model for private consumption, is presented.

The model is as follows:

$$\mathbf{p}' = \mathbf{p}'\mathbf{DTS_{IC}B_{IC}b_{IC}}' + (\mathbf{pve}' \circ (\mathbf{i}' - \mathbf{jx}') + \mathbf{pvx}' \circ \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}')$$

$$= \mathbf{p}'\mathbf{DTS_{IC}B_{IC}b_{IC}}' \qquad (\textbf{indirect cost effects})$$

$$+ \mathbf{p}'\mathbf{DTS_{CP}B_{CP}b_{CP}}' \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}') \qquad (\textbf{induced cost effects I})$$

$$+ \mathbf{pgx}' \circ (\mathbf{i}' - \mathbf{b_{CP}}') \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}') \qquad (\textbf{induced cost effects II})$$

$$+ \mathbf{pvx}' \circ \mathbf{jx}' \circ (\mathbf{i}' - \mathbf{b_{IC}}') \text{..........} (\textbf{direct cost effects}) \text{..........} (5)$$

where:

pve : Price index for GVA, which is variable in relation to changes in consumer prices by place of production and by sector

jx : The share of GVA, which is not variable in relation to changes in consumer prices by place of production and by sector

pvx : Price index for GVA, which is not variable in relation to changes in consumer prices by place of production and by sector

$\mathbf{S_{CP}}$: Shopping at the place of commodity market as share of total demand, by place of residence and by commodity

$\mathbf{B_{CP}}$: The use matrix for private consumption (private consumption by commodity as share of GVA by place of residence)

gx : The share of income not variable to changes in consumer prices by place of residence by type of production factor

pgx : Price index for income not variable to changes in consumer prices by place of residence by type of production factor

J : Employment by place of residence as share of total variable employment by place of production by type of production factor

G : Employment by type of production factor as share of total employment, by place of production by sector

In this extended model the step from consumer prices to the cost index of GVA has been included. The term $\mathbf{v}'$ (GVA cost index by sector) in equation 1 has been replaced by the last two terms in equation 5, which represent the induced cost effects (the $\mathbf{pve}' \circ (\mathbf{i}' - \mathbf{jx}')$ -term) and the exogenous fixed cost effects (the $\mathbf{pvx}' \circ \mathbf{jx}'$-term). The induced cost effects represent a transformation from place of commodity market through place of residence to place of production.

Looking at equation 5 in more detail, prices are transformed in a number of steps involving changes in the cost index originating from changes in prices for private consumption (the “induced cost effects I” in equation 5), and changes in the cost index originating from other sources than changes in prices for private consumption at place of residence (the “induced cost effects II” in equation 5) and changes originating from other sources at place of production (the “direct cost effects” in equation 5). First, changes in prices for private consumption are assumed to be passed on to the income at the place of residence, which in turn are transformed from place of residence to place of production using a matrix for commuting ($\mathbf{J}$) and further to the GVA cost index by sector (the “induced cost effects I”) using a matrix ($\mathbf{G}$)for employment structure by sector and by place of production. Second, other sources at the place of residence than consumer prices might influence the current income, which are then transformed from the place of residence to the place of production and further to the GVA cost index (the “induced cost effects II”) (second term). Finally, changes in the fixed GVA cost index (such as productivity-related changes in income determination) transform exogenous changes in GVA to factor payments.

Together with the cost index for the GVA and the intermediate consumption (first term in equation 5) price index prices of production by sector can now be found.

The cost-price model can be solved as follows:

$$\mathbf{p}' = \begin{bmatrix} \mathbf{I} \\ -\mathbf{DTS_{IC}B_{IC}b_{IC}}' \\ -\mathbf{DTS_{CP}B_{CP}b_{CP}}' \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}') \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{pgx}' \circ (\mathbf{i}' - \mathbf{b_{CP}}') \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}') \\ +\mathbf{pvx}' \circ \mathbf{jx}' \circ (\mathbf{i}' - \mathbf{b_{IC}}') \end{bmatrix} \qquad (6\mathbf{a})$$

The power series expansion of the analytical solution to the model is as follows:

$$\mathbf{p}' = \begin{bmatrix} \mathbf{pgx}' \circ (\mathbf{i}' - \mathbf{b_{CP}}') \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}') \\ +\mathbf{pvx}' \circ \mathbf{jx}' \circ (\mathbf{i}' - \mathbf{b_{IC}}') \end{bmatrix} \begin{bmatrix} \mathbf{I} \\ +(\mathbf{DTS_{IC}B_{IC}b_{IC}}' + \mathbf{DTS_{CP}B_{CP}b_{CP}}' \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}'))^1 \\ +(\mathbf{DTS_{IC}B_{IC}b_{IC}}' + \mathbf{DTS_{CP}B_{CP}b_{CP}}' \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}'))^2 \\ +(\mathbf{DTS_{IC}B_{IC}b_{IC}}' + \mathbf{DTS_{CP}B_{CP}b_{CP}}' \circ \mathbf{JG}(\mathbf{i}' - \mathbf{jx}') \circ (\mathbf{i}' - \mathbf{b_{IC}}'))^3 \\ +\ldots\ldots \end{bmatrix} \qquad (6\mathbf{b})$$

The price index for gross output is a function of

- the cost index related to the exogenous "direct cost effects" at the place of production (pvx),
- the cost index originating from other sources than changes in prices for private consumption at place of residence (pgx),
- the cost-price multiplier, which reflects the spillover and feedback mechanism in the system of formation of cost and prices, including the make matrix (D), the interregional trade matrix (T), shopping matrices for intermediate and private consumption (S_{IC} and S_P) etc.

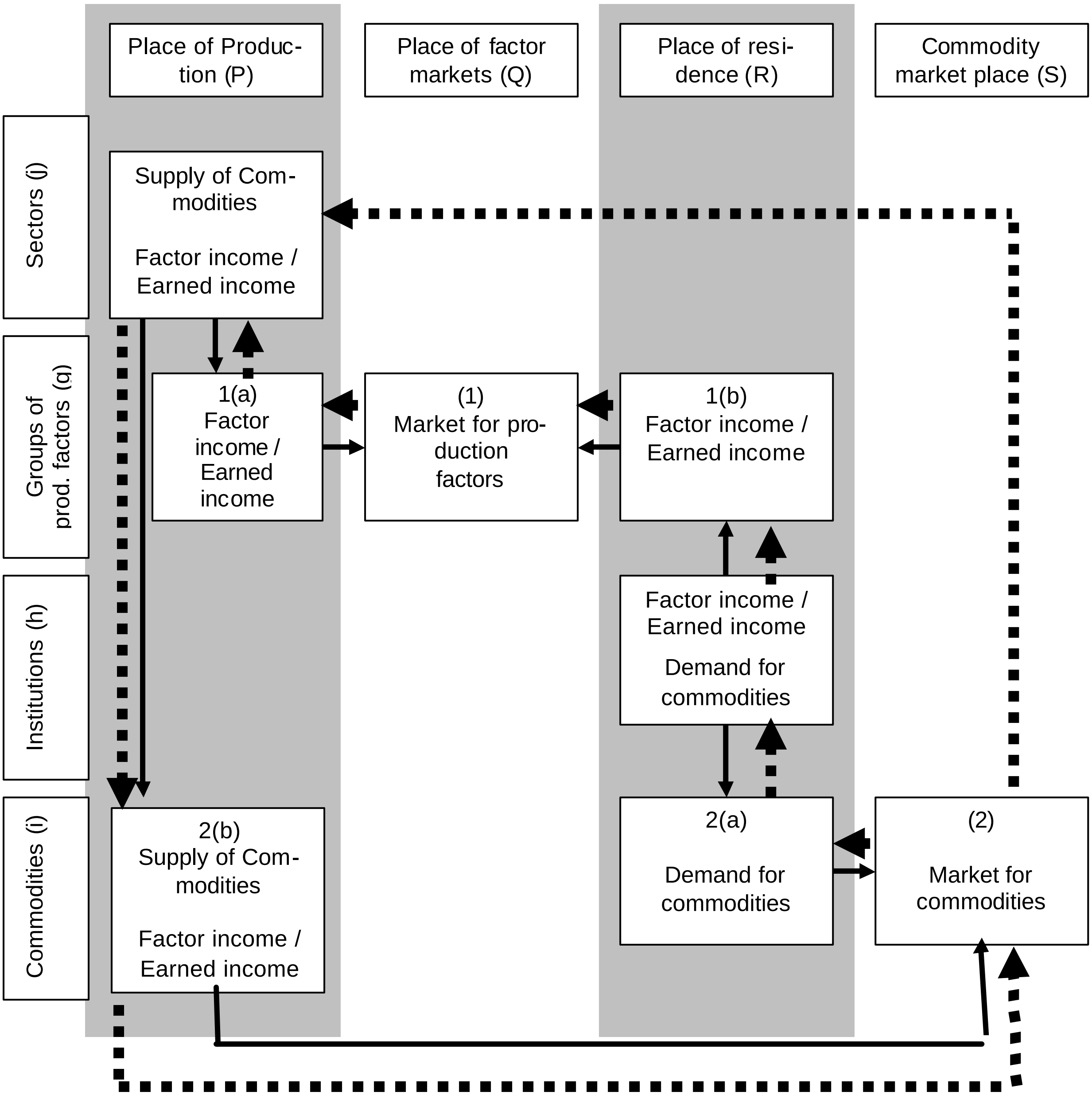
The solution shows that the price and cost effects are higher, the greater the initial exogenous cost push (pvx or pgx) are and smaller the higher the leakages in terms of out-ward trade ($\mathbf{T}$), outward shopping ($\mathbf{S_{IC}}$ and $\mathbf{S_{CP}}$) and commuting ($\mathbf{J}$) are.

4. The general interregional price model for local and urban economies[1]

There are three fundamental dimensions in the general price model, following the two-by-two-by-two principle. The two-by-two-by-two modelling principle involves use of a basic spatial accounting system with three dimensions (Madsen & Jensen-Butler 2005). First, there is a balance between demand and supply involving both producers and households. Second, there is a balance between demand and supply in both the commodity market and the factor market. Third, for both demand and supply in the commodity and factor markets origins and destinations are identified and spatial equilibrium is obtained. The general model structure is presented in figure 1.

[1] In this paper only the cost circle of the general model is presented. But a similar structure is applicable for the dual model, the real circle in the general model.

Figure 1
The conceptual basis of spatial social accounts and the price and cost model



The price circle moves anti-clockwise and follows the structure presented in the general Leontief and Miyazawa quantity model (Madsen 2007). This price model presented in figure 1 as compared with equation 6 has been extended to include the place of factor market (Q) and institutions (h) and a foreign sector.

4.1 The equations of the model

In the following the general interregional price model is presented both in equation form and graphically. In the appendix the equations of the model are presented in structural form with the partial solution[2]. The equations follow the cost and price circle as illustrated in figure 1. The model can be seen as a national model (the Leontief and Miyazawa model), where a spatial dimension (reading horizontally) and a social accounting dimension (reading vertically) have been included.

The presentation of the model commences in the upper left corner of figure 1 (cell Pj). In this cell the prices of production at the place of production and by sectors are determined. This corresponds to the last equation A.22 (appendix 1), where prices of production ($px_j^P{}'$) are a function of prices of intermediate consumption ($pu_{IC,j}^P{}'$) and GVA ($pv_j^P{}'$). “u” is a variable representing demand. The subscript (IC) indicates intermediate consumption and (j) the sector. The superscript shows that the prices of production, intermediate consumption and GVA are determined at the place of production (P).

Next, the price of gross output is transformed from sector prices into commodity prices (from cell Pj to Pi). This corresponds to equation A.1. Going through the equations the sequential structure of the cost-price circle is clear and follows the graphical presentation in figure 1. The cost price circuit corresponds to the interregional Leontief and Miyazawa price model and moves anticlockwise in figure 1. Continuing in the lower left corner (cell Pi), prices of production determine foreign export prices (equation A.2) and prices for domestic trade (equation A.3). Prices are transformed from place of production (cell Pi) to place of commodity market (cell Si). Here the domestic price index is merged with the price index for foreign imports to form the composite local demand price index (equation A.4). Then the cost and price circle is divided into two. In equations A.5-A.9, the indirect effects through intermediate consumption are determined, whilst the induced income formation is determined in equations A.10-A.21.

The prices of intermediate consumption are transformed from place of commodity market (Si) to place of production (Pi) and from (Pi) commodities to sectors (Pj) closing the indirect effects subcircle.

In the induced effects sub-circle the price index for private consumption is transformed from place of commodity market (Si) to the place of residence (Ri). Then the impacts on income by household arising from changes in consumer prices are determined, transforming prices from commodities to type of institutions (from Ri to Rh). Now follows the transformation from fixed prices to current prices and the effects on income from changes in private consumption in current prices are included. For the cost index for disposable income it is assumed that the price index for private consumption $(b_{CP,h}^R{}')$ is reflected only according to the private consumption share of income, whereas other factors $(pvxh_h^R{}')$ are reflected through the saving share $(i'-b_{CP,h}^R{}')$. Then the income cost index is transformed from type of institution to factor group (from Rh to Rg). It is assumed that the cost index $(pvx_g^R{}')$ for a share income $(gx_g^R{}')$ is determined by exogenous factors at the place of residence. Further, the effects on income arising from index cost index are transformed from place of residence to place of production (from Rg to Qg and to Pg) and transformed into impacts on value added by sector (from Pg to Pj). It is assumed that the cost index $(pvx_j^P{}')$ for a share income $(jx_j^P{}')$ is determined by exogenous factors at the place of production. Finally, value added is added to in-

[2] In another paper the equations in the real circle are shown and the mathematical solution to this model system is presented together with the simultaneous solution of the general local or urban model. This is the reason for denoting the analytical solution partial.

termediate consumption both in current prices, closing the cost and price circle (equation A.22).

In the general model both domestic and foreign sectors are represented in all markets. Costs and prices are thus involved in not only international trade in commodities, but also in other types of international interaction. This includes cross-border commuting (commuting income flows to and from abroad), border shopping (one-day tourist expenditure) and tourists' trips in both directions being included in formation of prices. This extension is included to make the model general as most regional systems interact with "the rest of the world".

4.2 The analytical solution for the general interregional price model

The model can now be solved by straightforward insertion. By inserting equation A.22 into equation A.21, and further down the set of equations to equation A.11 (the induced effects subcircle). This is followed by inserting equation A.10 into equation A.9, and further down the set of equations to equation A.6 (the indirect effects subcircle). Now, the equation can be solved for the price of gross output by sector ($px_j^P{}'$) as can be seen in equation A.24a.

From A.24a it can be seen that the price of the gross output by sector ($px_j^P{}'$) can be expressed as a product of the exogenous cost and price indices (the first part of the equation) and a cost and price multiplier (the second part of the equation). The exogenous cost and price indices include a) a cost index for income ($\mathbf{pvx_h^R}'$) for the part of income which is not influenced by price changes, b) a price index for foreign imports ($\mathbf{pz_i^{S,F}}'$) and c) price indices for other commodities purchased abroad including cross-border shopping ($\mathbf{pu_{IC,i}^{P,F}}'$ and $\mathbf{pu_{CP,i}^{P,F}}'$), as well a cost index for income earned by non-residents ($\mathbf{pv_g^{P,F}}'$). The cost and price multiplier consists of the usual coefficients for intermediate and private consumption ($\mathbf{b_{IC,j}^P}$ and $\mathbf{b_{CP,h}^P}$), trade, shopping and commuting coefficients ($\mathbf{T_i^{S,P}}$, $\mathbf{S_{IC,i}^{P,S}}$ & $\mathbf{S_{CP,i}^{R,S}}$ and $\mathbf{J_g^{P,Q}}$ & $\mathbf{J_g^{Q,R}}$) together with foreign trade, shopping and commuting shares etc.

$$
\begin{aligned}
\mathbf{px}_{j}^{P}{}' = & \left[\mathbf{pz}_{i}^{S,F}{}' \circ \mathbf{d}_{i}^{S,F}{}' \left[\begin{array}{l} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{array} \right] \right. \\
& + \mathbf{pu}_{IC,i}^{P,F}{}' \circ \mathbf{b}_{IC,i}^{P,F}{}' \mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\
& + \mathbf{pu}_{CP,i}^{R,F}{}' \circ \mathbf{b}_{CP,i}^{R,F}{}' \mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
& + \mathbf{pvx}_{h}^{R}{}' \circ (\mathbf{i}' - \mathbf{b}_{CP,h}^{R}{}')' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
& + \mathbf{pvx}_{g}^{R}{}' \circ \mathbf{gx}_{g}^{R}{}' \circ \mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q}(\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}') \circ \mathbf{J}_{j,g}^{P}(\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
& + \mathbf{pv}_{g}^{P,F}{}' \circ \mathbf{j}_{g}^{P,F}{}' \mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
& \left. + \mathbf{pvx}_{j}^{P}{}' \circ \mathbf{jx}_{j}^{P}{}' \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \right] \\
& \left[\mathbf{I} - \mathbf{D}_{j,i}^{P}\mathbf{T}_{i}^{S,P} \circ (\mathbf{i}' - \mathbf{d}_{i}^{S,F}{}') \left[\begin{array}{l} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{array} \right] \right]^{-1}
\end{aligned}
$$

................(**A**.24**a**) **and** (7)

5. The general price model – and LINE

LINE is an interregional general equilibrium model constructed for Danish municipalities (Madsen et al. 2001, Madsen & Jensen-Butler 2004). LINE consists of a quantity and a price model. The spatial *two-by-two-by-two* principle has been the guiding principle for the construction of both the quantity and the price model. However, there are some differences between the price model in LINE and a price model based upon a pure two-by-two-by-two principle as described above.

The structure of the price model in LINE follows the basic interregional general equilibrium model shown in figure 1 with:

- Factor markets and commodity markets
- Demand and supply in both markets
- Origins and destinations in all interactions.

Some simplifications and extensions are, however, incorporated. The general price model is adjusted as was the case for the quantity model:

1. The market of factors has been excluded from the price model in LINE.
2. Only factor income from labour receives full treatment.
3. Interactions between factor groups, households and governmental sectors are included in the price model in LINE.
4. Prices on consumption by institutions (households) both from a decision-making or a behavioural point of view must be divided into two nested steps.
5. Prices on private consumption have been divided into local private consumption and domestic tourism.
6. Different price concepts are included in the price model, reflecting the fact that different variables for economic activity use different price concepts. For goods and services, total expenditures at the place of commodity market are measured in market prices. Supply of commodities entering the goods and services market is modelled in basic prices. Basic prices are defined as the value of production at the factory, not including net commodity taxes paid by the producer. Going from basic prices to market/buyer prices in the price model involves addition of commodity taxes and trade margins, both in current prices. Changes in commodity tax and trade margin shares are exogenous variables in the price model in LINE.

6. Solving the general quantity and price model simultaneously

There are links between the quantity model and the price model. These links reflect links in the regional economy. On the one hand, prices are a function of exogenous costs and prices and a system of weights originating from the quantity model. On the other hand economic activity in the quantity model depends upon price dependent demand, such as foreign export.

In the classical version of the price model – the institutional sector-by-sector model shown in equation 1 – the exogenous cost and price variable is the GVA-deflator, whereas the weight system is the A-matrix. In the general interregional price model the exogenous cost and price variables are the GVA-deflator, foreign import prices etc., whereas the weight system is the system of transformations of quantities from demand to production or from production to demand through the interregional system of interaction.

In the formulation of the general interregional price model, the specification of the interaction between quantity system and prices in the general interregional price model is fully specified, because all weights from the quantity model have been included in the determination of prices (see equation 7 above or equation A.24). In condensed form the prices (for gross output) in the general interregional price model are determined by exogenous cost and prices and a system of weights determining the prices:

$$\mathbf{px}_j^{P}{}' = \mathbf{PricePreModel}\left[\mathbf{pz}_i^{S,F}{}', \mathbf{pu}_{i,IC}^{P,F}{}', \mathbf{pu}_{i,CP}^{R,F}{}', \mathbf{pvx}_h^{R}{}', \mathbf{pvx}_g^{R}{}', \mathbf{pvg}_g^{P,F}{}', \mathbf{pvx}_j^{P}{}'\right]\left[\mathbf{I} - \mathbf{A}_{j\,to\,j}^{PriceModel,Interreg}\right]^{-1} \ldots\ldots\ldots\ldots(\mathbf{A}.24\mathbf{a})\ \mathbf{or}\ (8)$$

where:

$$\mathbf{A}_{j\,to\,j}^{Pricemodel,Interreg} = \mathbf{D}_{j,i}^{P}\mathbf{T}_i^{S,P} \circ (\mathbf{i}' - \mathbf{d}_i^{S,F}{}')\begin{bmatrix} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC\,j}^{P}{}' \\ +\mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP\,h}^{R}{}'\mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}')\mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{bmatrix}$$

On the basis of prices for production, prices for specific demand components, such as price for export commodities can be determined adding a post model transforming prices on gross output into prices for the specific demand component:

$$\begin{aligned} \mathbf{pz}_i^{P,F}{}' &= \mathbf{PricePreModel}\left[\mathbf{pz}_i^{S,F}{}', \mathbf{pu}_{i,IC}^{P,F}{}', \mathbf{pu}_{i,CP}^{R,F}{}', \mathbf{pvx}_h^{R}{}', \mathbf{pvx}_g^{R}{}', \mathbf{pvg}_g^{P,F}{}', \mathbf{pvx}_j^{P}{}'\right]\left[\mathbf{I} - \mathbf{A}_{j\,to\,j}^{PriceModel,Interreg}\right]^{-1}\mathbf{D}_{j,i}^{P} \\ &= \mathbf{PricePreModel}\left[\mathbf{pz}_i^{S,F}{}', \mathbf{pu}_{i,IC}^{P,F}{}', \mathbf{pu}_{i,CP}^{R,F}{}', \mathbf{pvx}_h^{R}{}', \mathbf{pvx}_g^{R}{}', \mathbf{pvg}_g^{P,F}{}', \mathbf{pvx}_j^{P}{}'\right]\left[\mathbf{I} - \mathbf{A}_{j\,to\,j}^{PriceModel,Interreg}\right]^{-1} \\ &\quad \circ \mathbf{PricePostModel} \ldots\ldots\ldots\ldots(\mathbf{A}.24\mathbf{a})\ \mathbf{or}\ (8) \end{aligned}$$

In most cases in the real economy prices influence quantities, such as foreign export, which changes if foreign export prices change. However, in the quantity model there are no links between the price variables in the cost-price model and the exogenous variables in the quantity model. In the quantity model economic activity, such as gross output, is explained only by quantity-model variables, such as coefficients entering into the multiplier (the A-matrix in the classical institutional sector-by-sector model) and the exogenous demand (foreign export, governmental consumption and investments in the classical model). In the condensed formulation of the general interregional quantity model, gross output is determined as follows:

$$\mathbf{x}_j^{P} = \left[\mathbf{I} - \mathbf{A}_{j\,to\,j}^{Interreg}\right]^{-1}\mathbf{QuantityPostModel}\left[\mathbf{z}_i^{P,F,f}, \mathbf{u}_{i,IC}^{S,F,f}, \mathbf{u}_{i,CP}^{S,F,f}, \mathbf{u}_{i,CO}^{S,f}, \mathbf{u}_{i,IR}^{S,f}, \mathbf{q}_g^{R,F}\right] \ldots\ldots\ldots\ldots(9)$$

where:

$$A_{j\,to\,j}^{Interreg} = \begin{bmatrix} I - D_{i,j}^{P}T_i^{S,P}(i - d_i^{S,F}) \circ S_{i,IC}^{P,S}(i - s_{i,IC}^{P,F}) \circ B_{IC,j,i}^{P}b_{j,IC}^{P} \\ -D_{i,j}^{P}T_i^{S,P}(i - d_i^{S,F}) \circ S_{i,CP}^{R,S}(i - b_{i,CP}^{R,F}) \circ B_{CP,h,i}^{R}b_{h,CP}^{R} \circ (pu_{h,CP}^{R})^{-1} \circ H_{g,h}^{R} \\ pv_g^{R,D} \circ v_g^{R,D} \circ J_g^{Q,R}J_g^{P,Q}(i - j_g^{P,F}) \circ G_{g,j}^{P}g_j^{P} \end{bmatrix}^{-1} \qquad (10)$$

Extending the quantity model with price dependency, different formulations are possible. First, it can be assumed that prices enter into the determination of the exogenous demand, such as foreign exports. Second, it can be assumed that the coefficients in the multiplier matrix are dependent on prices.

Mathematically, linking exogenous demand to prices for exogenous demand is straightforward. Assuming a linear relation between foreign export and foreign export prices:

$$\mathbf{z}_{\mathbf{i}}^{\mathbf{P,F,f}} = \varepsilon_0 + \varepsilon_1 \mathbf{pz}_{\mathbf{i}}^{\mathbf{S,F}} \text{.................................(11)}$$

Solving the combined general interregional quantity and price model gives:

$$\begin{aligned}
\mathbf{x}_{\mathbf{j}}^{\mathbf{P}} &= \left[\mathbf{I} - \mathbf{A}_{\mathbf{j\,to\,j}}^{\mathbf{Interreg}}\right]^{-1} \mathbf{QuantityPostModel}\left[\mathbf{z}_{\mathbf{i}}^{\mathbf{P,F,f}}, \mathbf{u}_{\mathbf{i,I\,C}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,P}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,O}}^{\mathbf{S,f}}, \mathbf{u}_{\mathbf{i,I\,R}}^{\mathbf{S,f}}, \mathbf{q}_{\mathbf{g}}^{\mathbf{R,F}}\right] \\
&= \left[\mathbf{I} - \mathbf{A}_{\mathbf{j\,to\,j}}^{\mathbf{Interreg}}\right]^{-1} \mathbf{QuantityPostModel}\begin{bmatrix} \mathbf{pz}_{\mathbf{i}}^{\mathbf{S,F}\,\prime} \circ \varepsilon_1 + \varepsilon_0, \\ \mathbf{u}_{\mathbf{i,I\,C}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,P}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,O}}^{\mathbf{S,f}}, \mathbf{u}_{\mathbf{i,I\,R}}^{\mathbf{S,f}}, \mathbf{q}_{\mathbf{g}}^{\mathbf{R,F}} \end{bmatrix} \\
&= \left[\mathbf{I} - \mathbf{A}_{\mathbf{j\,to\,j}}^{\mathbf{Interreg}}\right]^{-1} \mathbf{QuantityPostModel}\begin{bmatrix} \mathbf{PricePreModel}\left[\mathbf{pz}_{\mathbf{i}}^{\mathbf{S,F}\,\prime}, \mathbf{pu}_{\mathbf{i,I\,C}}^{\mathbf{P,F}\,\prime}, \mathbf{pz}_{\mathbf{i}}^{\mathbf{S,F}\,\prime}, \mathbf{pu}_{\mathbf{i,C\,P}}^{\mathbf{R,F}\,\prime}, \mathbf{phx}_{\mathbf{h}}^{\mathbf{R}\,\prime}, \mathbf{ph}_{\mathbf{g}}^{\mathbf{P,F}\,\prime}\right] \\ \left[\mathbf{I} - \mathbf{A}_{\mathbf{j\,to\,j}}^{\mathbf{PriceModelInterreg}}\right]^{-1} (\mathbf{PricePostModel} \circ \varepsilon_1 + \varepsilon_0), \\ \mathbf{u}_{\mathbf{i,I\,C}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,P}}^{\mathbf{S,F,f}}, \mathbf{u}_{\mathbf{i,C\,O}}^{\mathbf{S,f}}, \mathbf{u}_{\mathbf{i,I\,R}}^{\mathbf{S,f}}, \mathbf{q}_{\mathbf{g}}^{\mathbf{R,F}} \end{bmatrix} \text{..(12)}
\end{aligned}$$

From this solution of the pure linear combined general interregional quantity and price model, assuming price dependency in the foreign export, it can be seen that production is determined by

- exogenous cost and price variables in the price model, such as GVA deflator, foreign import prices etc.
- the weight system for transformations of quantities from demand to production and from production to demand through the interregional system of interaction
- exogenous demand, such as governmental consumption etc.
- coefficients e_0 and e_1 in the foreign export price equation.

Mathematically, linking the coefficients for transformation between quantities from demand to production and from production to demand through the interregional system of interaction to changes in prices is much more complicated and cannot easily be solved.

7. Summary

In this paper the general interregional static price model for local or urban economies has been presented. The model represents an extension and integration of the interregional Leontief price model, which involves the indirect effects and a modification of the interregional Miyazawa quantity model to include the induced effects.

The general interregional price model is based upon the two-by-two-by-two principle including a) markets for commodities and factors, b) production units and institutional units and c) origin and destination for the demand and supply in the two markets. The general interregional price model includes a foreign sector and the analytical solution to the model is presented. The general interregional price model is compared with LINE, which is a local economic model for Danish regions with a structure similar to the structure of the general interregional and local price model.

Further, the establishment of a general static model, which integrates the interregional price and quantity models through a set of links is examined. Two types of links are identified, demand price links for exogenous demand, and price links determining structural coefficients. An analytical solution for the combined general static price and quantity model is presented.

Appendix

The equations for the general interregional quantity model for local and urban economies in structural form

Variables in the quantity model

The variables in the general interregional quantity model are denoted in the following way:

Variables

x:	Gross output by sector
px:	Price index for gross output by sector
D:	Make coefficient matrix
T:	Trade coefficient matrix
b:	Use coefficient vector of demand
z:	Trade vector
pz:	Price index for trade flows
B:	Use coefficient matrix of demand
pu:	Price index vector for demand
hx:	Share of income independent of consumer prices
phx:	Income index for income independent of consumer prices
G, H, J:	Income transformation coefficient matrices
g, h, j:	Income vectors
ph:	Income index by type of household
pg:	Income index by factor group
pv:	Income index by sector

Superscripts

P:	Place of production (regional axis)
Q:	Place of factor market (regional axis)
R:	Place of residence (regional axis)
S:	Place of commodity market (regional axis)
D:	Domestic
F:	Rest of the world
f:	Fixed prices

Subscripts

SAM-axes

j:	Sector (SAM-axis)
g:	Groups of factors (SAM-axis)
h:	Type of institution (SAM-axis)
i:	Commodity (SAM-axis)
IC:	Intermediate consumption
CP:	private consumption
CO:	Governmental consumption
IR:	Investments

The general interregional price model in structural form

$\mathbf{px}_i^{P}{}' = \mathbf{px}_j^{P}{}'\mathbf{D}_{j,i}^{P}$ ....(A.1) **From Pj to Pi**

$\mathbf{pz}_i^{P,F}{}' = \mathbf{px}_i^{P}{}'$ ....(A.2)

$\mathbf{pz}_i^{P,D}{}' = \mathbf{px}_i^{P}{}'$ ....(A.3)

$\mathbf{pz}_i^{S,D}{}' = \mathbf{pz}_i^{P,D}{}'\mathbf{T}_i^{S,P}$ ....(A.4) **From Pi to Si**

$\mathbf{pu}_i^{S}{}' = \mathbf{pz}_i^{S,D}{}' \circ (\mathbf{i}' - \mathbf{d}_i^{S,F}{}') + \mathbf{pz}_i^{S,F}{}' \circ \mathbf{d}_i^{S,F}{}'$ ....(A.5)

$\mathbf{pu}_{IC,i}^{S}{}' = \mathbf{pu}_i^{S}{}'$ ....(A.6)

$\mathbf{pu}_{IC,i}^{P,D}{}' = \mathbf{pu}_{IC,i}^{S}{}'\mathbf{S}_{IC,i}^{P,S}$ ....(A.7) **From Si to Pi**

$\mathbf{pu}_{IC,i}^{P}{}' = \mathbf{pu}_{IC,i}^{P,D}{}' \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}') + \mathbf{pu}_{IC,i}^{P,F}{}' \circ \mathbf{b}_{IC,i}^{P,F}{}'$ ....(A.8)

$\mathbf{pu}_{IC,j}^{P}{}' = \mathbf{pu}_{IC,i}^{P}{}'\mathbf{B}_{IC\,j\,i}^{P}$ ....(A.9) **From Pi to Pj**

$\mathbf{pu}_{CP,i}^{S}{}' = \mathbf{pu}_i^{S}{}'$ ....(A.10)

$\mathbf{pu}_{CP,i}^{R,D}{}' = \mathbf{pu}_{CP,i}^{S}{}'\mathbf{S}_{CP,i}^{R,S}$ ....(A.11) **From Si to Ri**

$\mathbf{pu}_{CP,i}^{R}{}' = \mathbf{pu}_{CP,i}^{R,D}{}' \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}') + \mathbf{pu}_{CP,i}^{R,F}{}' \circ \mathbf{b}_{CP,i}^{R,F}{}'$ ....(A.12)

$\mathbf{pu}_{CP,h}^{R}{}' = \mathbf{pu}_{CP,i}^{R}{}'\mathbf{B}_{CP\,h\,i}^{R}$ ....(A.13) **From Ri to Rh**

$\mathbf{pv}_h^{R}{}' = \mathbf{pu}_{CP,h}^{R}{}' \circ \mathbf{b}_{CP,h}^{R}{}' + \mathbf{pvx}_h^{R}{}' \circ (\mathbf{i}' - \mathbf{b}_{CP,h}^{R}{}')'$ ....(A.14)

$\mathbf{pve}_g^{R}{}' = \mathbf{pv}_h^{R}{}'\mathbf{H}_{g,h}^{R}$ ....(A.15) **From Rh to Rg**

$\mathbf{pv}_g^{R}{}' = \mathbf{pve}_g^{R}{}' \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}') + \mathbf{pvx}_g^{R}{}' \circ \mathbf{gx}_g^{R}{}'$ ....(A.16)

$\mathbf{pv}_g^{Q}{}' = \mathbf{pv}_g^{R}{}'\mathbf{J}_g^{Q,R}$ ....(A.17) **From Rg to Qg**

$\mathbf{pv}_g^{P,D}{}' = \mathbf{pv}_g^{Q}{}'\mathbf{J}_g^{P,Q}$ ....(A.18) **From Qg to Pg**

$\mathbf{pv}_g^{P}{}' = \mathbf{pv}_g^{P,D}{}' \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}') + \mathbf{pv}_g^{P,F}{}' \circ \mathbf{j}_g^{P,F}{}'$ ....(A.19)

$\mathbf{pve}_j^{P}{}' = \mathbf{pv}_g^{P}{}'\mathbf{J}_{j,g}^{P}$ ....(A.20) **From Pg to Pj**

$\mathbf{pv}_j^{P}{}' = \mathbf{pve}_j^{P}{}' \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') + \mathbf{pvx}_j^{P}{}' \circ \mathbf{jx}_j^{P}{}'$ ....(A.21)

$\mathbf{px}_j^{P}{}' = \mathbf{pu}_{IC,j}^{P}{}' \circ \mathbf{b}_{IC,j}^{P}{}' + \mathbf{pv}_j^{P}{}' \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}')$ ....(A.22)

The general interregional price model in reduced form:

$$
\begin{aligned}
\mathbf{px}_j^{P}{}' = {} & \mathbf{px}_j^{P}{}'\mathbf{D}_{j,i}^{P}\mathbf{T}_i^{S,P} \circ (\mathbf{i}' - \mathbf{d}_i^{S,F}{}')\left[\begin{array}{l} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}'\mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}')\mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{array}\right] \\
& + \left[\begin{array}{l}
\mathbf{pz}_i^{S,F}{}' \circ \mathbf{d}_i^{S,F}{}' \left[\begin{array}{l} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}'\mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}')\mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{array}\right] \\
+ \mathbf{pu}_{IC,i}^{P,F}{}' \circ \mathbf{b}_{IC,i}^{P,F}{}'\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\
+ \mathbf{pu}_{CP,i}^{R,F}{}' \circ \mathbf{b}_{CP,i}^{R,F}{}'\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}'\mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}')\mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_h^{R}{}' \circ (\mathbf{i}' - \mathbf{b}_{CP,h}^{R}{}')'\mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_g^{R}{}')\mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_g^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_g^{R}{}' \circ \mathbf{gx}_g^{R}{}' \circ \mathbf{J}_g^{Q,R}\mathbf{J}_g^{P,Q}(\mathbf{i}' - \mathbf{j}_g^{P,F}{}') \circ \mathbf{J}_{j,g}^{P}(\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pv}_g^{P,F}{}' \circ \mathbf{j}_g^{P,F}{}'\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_j^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_j^{P}{}' \circ \mathbf{jx}_j^{P}{}' \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}')
\end{array}\right] \quad \text{................(A.23)}
\end{aligned}
$$

The solution to the general interregional price model:

$$
\mathbf{px}_{j}^{P}{}' = \begin{bmatrix}
\mathbf{pz}_{i}^{S,F}{}' \circ \mathbf{d}_{i}^{S,F}{}' \begin{bmatrix} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{bmatrix} \\
+ \mathbf{pu}_{IC,i}^{P,F}{}' \circ \mathbf{b}_{IC,i}^{P,F}{}' \mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\
+ \mathbf{pu}_{CP,i}^{R,F}{}' \circ \mathbf{b}_{CP,i}^{R,F}{}' \mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_{h}^{R}{}' \circ (\mathbf{i}' - \mathbf{b}_{CP,h}^{R}{}')' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_{g}^{R}{}' \circ \mathbf{gx}_{g}^{R}{}' \circ \mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q}(\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}') \circ \mathbf{J}_{j,g}^{P}(\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pv}_{g}^{P,F}{}' \circ \mathbf{j}_{g}^{P,F}{}' \mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \\
+ \mathbf{pvx}_{j}^{P}{}' \circ \mathbf{jx}_{j}^{P}{}' \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}')
\end{bmatrix}
$$

$$
\begin{bmatrix} \mathbf{I} - \mathbf{D}_{j,i}^{P}\mathbf{T}_{i}^{S,P} \circ (\mathbf{i}' - \mathbf{d}_{i}^{S,F}{}') \begin{bmatrix} \mathbf{S}_{IC,i}^{P,S} \circ (\mathbf{i}' - \mathbf{b}_{IC,i}^{P,F}{}')\mathbf{B}_{IC,j,i}^{P} \circ \mathbf{b}_{IC,j}^{P}{}' \\ + \mathbf{S}_{CP,i}^{R,S} \circ (\mathbf{i}' - \mathbf{b}_{CP,i}^{R,F}{}')\mathbf{B}_{CP,h,i}^{R} \circ \mathbf{b}_{CP,h}^{R}{}' \mathbf{H}_{g,h}^{R} \circ (\mathbf{i}' - \mathbf{gx}_{g}^{R}{}')\mathbf{J}_{g}^{Q,R}\mathbf{J}_{g}^{P,Q} \circ (\mathbf{i}' - \mathbf{j}_{g}^{P,F}{}')\mathbf{J}_{j,g}^{P} \circ (\mathbf{i}' - \mathbf{jx}_{j}^{P}{}') \circ (\mathbf{i}' - \mathbf{b}_{IC,j}^{P}{}') \end{bmatrix} \end{bmatrix}^{-1}
$$

................(**A**.24**a**)

The power series expansion of the analytical solution to the general interregional price model

$$
\mathbf{px}_j^{P\,\prime} = \left[\begin{array}{l}
\mathbf{pz}_i^{S,F\,\prime} \circ \mathbf{d}_i^{S,F\,\prime} \left[\begin{array}{l} \mathbf{S}^{P,S}_{IC,i} \circ (\mathbf{i}' - \mathbf{b}^{P,F}_{IC,i}{}')\mathbf{B}^{P}_{IC,j,i} \circ \mathbf{b}^{P}_{IC,j}{}' \\ +\mathbf{S}^{R,S}_{CP,i} \circ (\mathbf{i}' - \mathbf{b}^{R,F}_{CP,i}{}')\mathbf{B}^{R}_{CP,h,i} \circ \mathbf{b}^{R}_{CP,h}{}'\,\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\,\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \end{array} \right] \\
\quad + \mathbf{pu}^{P,F}_{IC,i}{}' \circ \mathbf{b}^{P,F}_{IC,i}{}'\mathbf{B}^{P}_{IC,j,i} \circ \mathbf{b}^{P}_{IC,j}{}' \\
\quad + \mathbf{pu}^{R,F}_{CP,i}{}' \circ \mathbf{b}^{R,F}_{CP,i}{}'\mathbf{B}^{R}_{CP,h,i} \circ \mathbf{b}^{R}_{CP,h}{}'\,\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\,\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \\
\quad + \mathbf{pvx}^{R}_{h}{}' \circ (\mathbf{i}' - \mathbf{b}^{R}_{CP,h}{}')'\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\,\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \\
\quad + \mathbf{pvx}^{R}_{g}{}' \circ \mathbf{gx}^{R}_{g}{}' \circ \mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g}(\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}') \circ \mathbf{J}^{P}_{j,g}(\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \\
\quad + \mathbf{pv}^{P,F}_{g}{}' \circ \mathbf{j}^{P,F}_{g}{}'\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \\
\quad + \mathbf{pvx}^{P}_{j}{}' \circ \mathbf{jx}^{P}_{j}{}' \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}')
\end{array} \right]
$$

$$
\left[\begin{array}{l}
\mathbf{I} + \left[\mathbf{D}^{P}_{j,i}\mathbf{T}^{S,P}_{i} \circ (\mathbf{i}' - \mathbf{d}^{S,F}_{i}{}') \left[\begin{array}{l} \mathbf{S}^{P,S}_{IC,i} \circ (\mathbf{i}' - \mathbf{b}^{P,F}_{IC,i}{}')\mathbf{B}^{P}_{IC,j,i} \circ \mathbf{b}^{P}_{IC,j}{}' \\ +\mathbf{S}^{R,S}_{CP,i} \circ (\mathbf{i}' - \mathbf{b}^{R,F}_{CP,i}{}')\mathbf{B}^{R}_{CP,h,i} \circ \mathbf{b}^{R}_{CP,h}{}'\,\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \end{array} \right] \right]^{1} \\
\left[\mathbf{D}^{P}_{j,i}\mathbf{T}^{S,P}_{i} \circ (\mathbf{i}' - \mathbf{d}^{S,F}_{i}{}') \left[\begin{array}{l} \mathbf{S}^{P,S}_{IC,i} \circ (\mathbf{i}' - \mathbf{b}^{P,F}_{IC,i}{}')\mathbf{B}^{P}_{IC,j,i} \circ \mathbf{b}^{P}_{IC,j}{}' \\ +\mathbf{S}^{R,S}_{CP,i} \circ (\mathbf{i}' - \mathbf{b}^{R,F}_{CP,i}{}')\mathbf{B}^{R}_{CP,h,i} \circ \mathbf{b}^{R}_{CP,h}{}'\,\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \end{array} \right] \right]^{2} \\
\left[\mathbf{D}^{P}_{j,i}\mathbf{T}^{S,P}_{i} \circ (\mathbf{i}' - \mathbf{d}^{S,F}_{i}{}') \left[\begin{array}{l} \mathbf{S}^{P,S}_{IC,i} \circ (\mathbf{i}' - \mathbf{b}^{P,F}_{IC,i}{}')\mathbf{B}^{P}_{IC,j,i} \circ \mathbf{b}^{P}_{IC,j}{}' \\ +\mathbf{S}^{R,S}_{CP,i} \circ (\mathbf{i}' - \mathbf{b}^{R,F}_{CP,i}{}')\mathbf{B}^{R}_{CP,h,i} \circ \mathbf{b}^{R}_{CP,h}{}'\,\mathbf{H}^{R}_{g,h} \circ (\mathbf{i}' - \mathbf{gx}^{R}_{g}{}')\mathbf{J}^{Q,R}_{g}\mathbf{J}^{P,Q}_{g} \circ (\mathbf{i}' - \mathbf{j}^{P,F}_{g}{}')\mathbf{J}^{P}_{j,g} \circ (\mathbf{i}' - \mathbf{jx}^{P}_{j}{}') \circ (\mathbf{i}' - \mathbf{b}^{P}_{IC,j}{}') \end{array} \right] \right]^{3} \\
\circ\circ\circ\circ
\end{array} \right]
$$

................(**A**.24**b**)

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Section 6:

Modelling Demography and the Regional Economy: An Interregional General Equilibrium Modelling Framework

Bjarne Madsen

Section 6

Modelling Demography and the Regional Economy:

An Interregional General Equilibrium Modelling Framework

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1. Abstract[1]

An ageing population is a challenge facing most economies in OECD countries today. Low fertility and longer average living ages will hollow out the economic basis for the majority of the OECD countries. In this paper a regional model including the age impact on the regional and local/urban economy is presented.

The age problem involves both an income/supply side and an expenditure/demand side. Level of income in a region/local area is determined by the productive part of the population and their productivity. As the share of population of older people increases, which has a below average productivity and labour participation rate, the process of ageing for most regions will lead to lower production and lower income in regions in most of the OECD countries.

On the demand side the consumption by old people (either the private consumption or the governmental consumption) will change. For the older population the demand will not increase, because increasing individual governmental consumption for age-specific commodities such as medicine and hospitals will be outweighed by a decrease in private consumption. But for the very old population, the total consumption will increase because the increase in cost in keeping the very old alive is often higher than the decrease in private consumption.

In this paper a comparative static, general, interregional, equilibrium model for local or urban economies is presented. The aim of the model is to illustrate the impact of comparative static shifts in the age structure of the population in terms of impact on average real disposable income (in total and by age group). The model includes the division of the population, the labour force, the employment and unemployment rate into age groups. The model includes the local, the interregional and the international levels, reflecting different equilibrating processes, where excess supply and demand can exist in certain markets, whereas equilibrium does not prevail in other markets. The theoretical model is formulated in changes and is solved for a quantity and a price side. Multipliers for the quantity and price side of the local economy are derived. The signs and the magnitudes for different types of areas of the ageing process are discussed.

The model can be formulated in different ways reflecting different time horizons and different regimes for regulation and barriers for interregional and international interaction: In the long run, interregional migration can equilibrate excess supply and demand in the domestic labour markets, whereas equilibration in the international demand and supply of labour depends on the regulation of international migration flows. Different specification of the model

1 I want to thank senior researcher Frank Jensen for comments and advice in the work with the mathematical formulation of the general interregional model in difference.

reflecting different regimes of interregional and international interaction and the time horizon in the equilibrating process are discussed.

The paper is organised as follows. In section 2 the basic model is presented, while section 3 includes the basic equations. The model is solved in section 4 and an interpretation of the model can be found in section 5 including a discussion of an alternative specification of the model reflecting different time horizons and different regimes for interregional and international interaction. Section 6 concludes the paper.

2. The model

In Madsen (2007a & 2007b) the two-by-two-by-two principle is used as the basic structure of the general, interregional, static quantity and price models in order to give a general overall picture of a local economy. In this paper, the model is transformed into a model in changes. In the model the labour market is modelled as an age-divided market. Non-linear functions in labour demand, productivity and labour-participation rates are included. Now, the two-by-two-by-two principle is presented. After that a model, which (compared to the general interregional linear quantity and price models) has been slightly simplified including non-linear labour demand, productivity and labour-participation rate functions, is examined. The model, which is formulated in changes, is solved analytically. Finally, the solutions to the modified quantity and the price models are presented and multipliers are examined and used to classify local areas into different archetypes.

2.1. The two-by-two-by-two principle – Basic concepts and dimensions in the interregional model

There are three fundamental dimensions in the general, interregional, quantity and price model, following the two-by-two-by-two principle (Madsen & Jensen-Butler 2005, Madsen 2007a & 2007b). First, both producers and households are represented in the model. Second, two markets (a commodity market and a factor market) are included in the general model. Third, interaction between markets and actors includes information on origins and destinations. For both actors and markets basic geographical concepts have been used as well as social accounting concepts for activities.

In factor markets supply and demand of production factors are to be found. Demand for production factors (g) is determined by production by sector (j) at the place of production (P). Factor demand by sector is transformed into factor demand by type of production factor (g). On the supply side, supply of production factors by type of institution (h) is transformed into supply by type of production factor (g). Supply of a production factor is related to the place of residence of the institution (R). The factor market is geographically assigned to the market place for factors (Q) (see figure 1).

Completing the presentation of the general model based on the two-by-two-by-two principle, in the commodity market there is a distinction between place of residence (R), the market place for commodities (S) and place of production (P). The market place for commodities links the demand for the commodity (from place of residence to the market place for commodities) to the supply of the commodity (from place of production to the market place for commodities). Before the transformation to the market place for commodities, the demand for commodities is transformed from institutional group (h) to commodity (i). On the supply side, production by sector (j) is transformed into production by commodity (i) and then supply is related geographically to the market place for commodities (S).

In comparison with this general, interregional, quantity and price model based upon the two-by-two-by-two principle, a 3-dimensional model has been used in this paper. The place of factor market (Q) and type of institution (h) have been omitted.

Second, this model is an open model in trade only opposite the general interregional model, which includes both domestic and foreign sectors in all markets. Thereby, it omits other types of international interaction, such as cross border commuting (income flows to and from abroad through commuting), border shopping, which includes one-day tourist expenditure in both directions, and tourism are excluded.

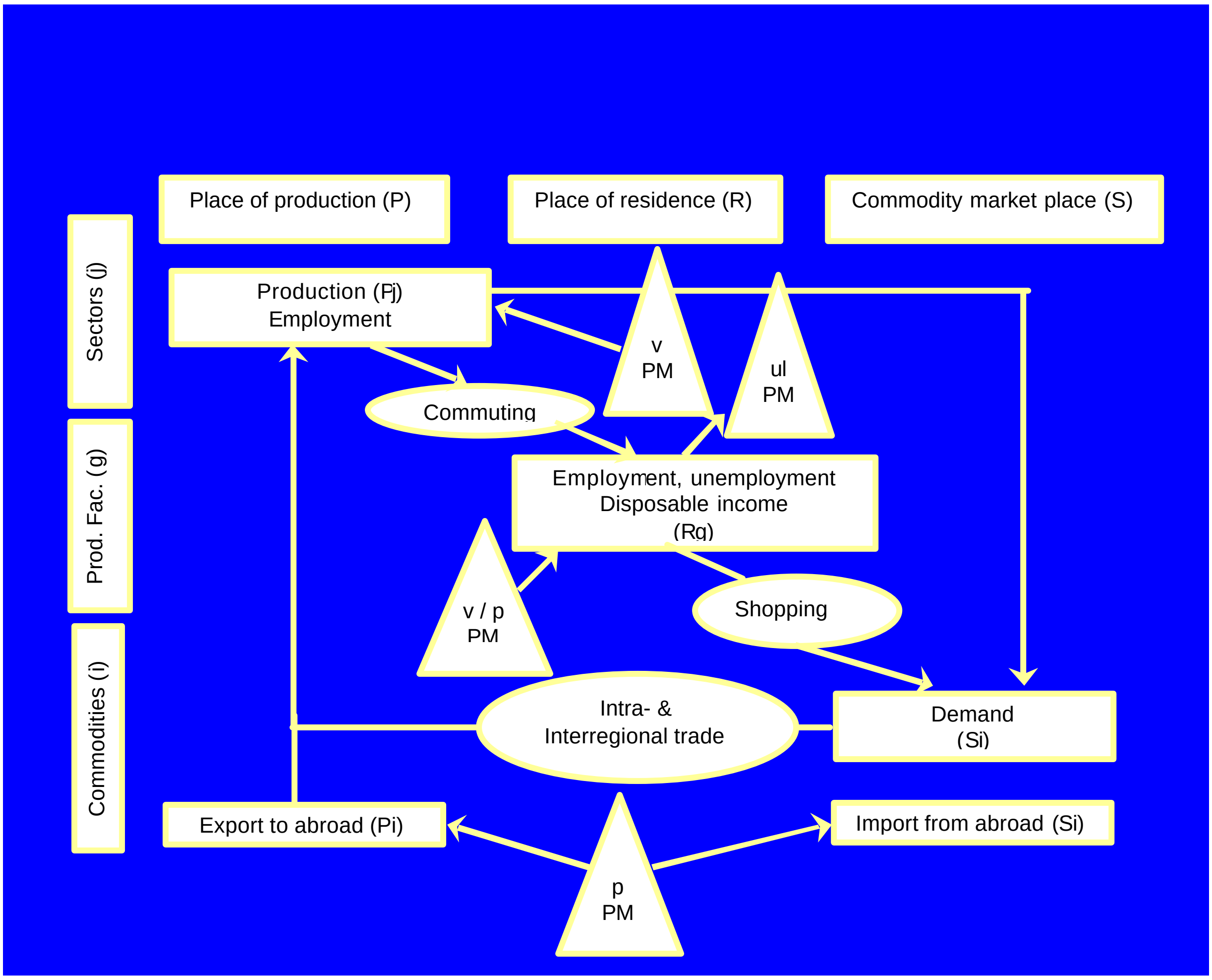
These exclusions are justified, because the model becomes smaller and more operational without loss of generality. Simplifications are necessary as one of the main aims of the model is to introduce more complex and non-linear behaviour equations for factor demand and productivity and labour-participation rate equations.

2.2. The general interregional quantity and the price submodels – a graphical presentation

The model by Madsen (2007a & 2007b) includes two submodels, the quantity and the price model. The two submodels are sequential models or models with a circular causal structure. In the quantity circuit the well known effects from demand on supply (income) and from income to demand are included. In the price circuit the spillover and feedback effects of cost and price changes using an adding-up principle based upon the assumption of perfect competition are modelled.

Taking the 3-dimensional model as point of departure, the two submodels are sequential models, which are represented in figure 1 and 2 below.

Figure 1. The real circle – the quantity submodel



Note: PM: Price submodel; ul: unemployment; p: prices; v: income rates.

The horizontal dimension is spatial and includes place of production (P), place of residence (R) and place of commodity market (S). Production activity is related to place of production. Factor rewards and income to production factors are related to place of residence and demand for commodities is assigned to place of commodity market. The vertical dimension follows with its threefold division the general structure of a SAM model. Production is related to activities (j); factor incomes are related to factors of production with labour classified by age (g), commodities are related to the supply and demand for commodities (i).

The real circuit – or the quantity model – corresponds to a demand-driven Keynesian model and moves sequentially and clockwise in figure 1. Starting in the upper left corner (Pj), production generates intermediate consumption demand and employment by sectors (j) at the place of production (P). The employment is transformed from sectors (j) to age groups (g) determined by relative income and from place of production (P) to place of residence (R) through a commuting model. Labour force at the place of residence depends upon population by age (g) and activity rates by age, which in turn depends upon age specific income rates. Labour force and employment determine the unemployment by age (g) at place of residence (R).

Real disposable income by age groups at the place of residence is determined by private consumption prices, employment and income rates (Rg). Real disposable income and commodity-specific consumption rates are the basis for determination of private consumption by place of residence (R) and by commodity (i). Private consumption is assigned to place of commodity market (Si) using a shopping model. Governmental consumption is determined by population by age (g) and the age and commodity (i) specific consumption rates at the place of residence (R). Governmental consumption by commodity (i) is transformed into commodity market place (Si), where the consumption takes place. Intermediate consumption at place of production (P) and by sector (j) is determined by gross output and transformed to place of commodity market (Si). Intermediate, private and governmental consumption together with investment constitute the total local demand for commodities (Si), by commodity. Local demand is met by imports from other regions and from abroad in addition to local production (Si). Through a trade model exports abroad and to other regions and production for the region itself are determined (Pi). Gross output by commodity is determined by this demand. Through a reverse make matrix the cycle returns to production by sector (Pj).

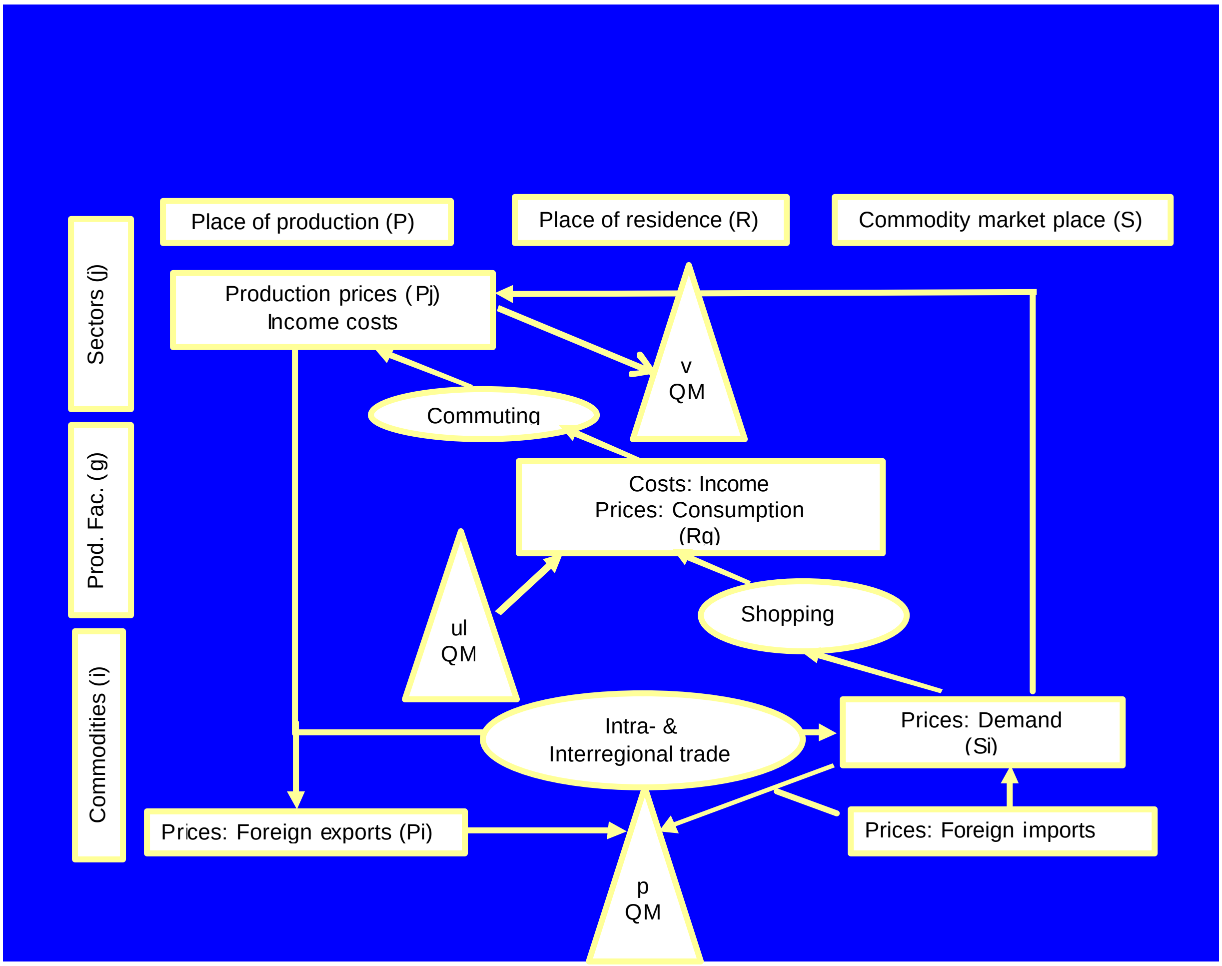
Economic activity in the real circle or the quantity model is affected by changes in prices and income: The anticlockwise cost/price circuit (or the price model) shown in Figure 2 corresponds to this dual problem. In the upper left corner a price index for production by place of production (P) and by sector (j) is determined by a cost approach (intermediate consumption and value added, Pj). Income rates affect the composition of labour in the production (from j to g), which in turn affect the productivity by sector (from g to j). Together with prices (price indices) on intermediate consumption income costs (income rates) affect prices (price indices) of the local production (Pj). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (i), which through relative changes in local competitiveness affects exports abroad (Pi). These are then transformed from place of production to place of demand (Si). Commodities for intermediate consumption enter into the next step in the production chain, through transformations from place of commodity market (S) to place of production (P) and from commodity (i) to sectors (j), determining prices of production (Pj). These prices are spread further in a round-by-round distribution process following a sequential modelling routine.

Finally, prices on private consumption are transformed from place of commodity market (S) to place of residence (R) and from commodities (i) to age groups (g). At the labour market

(Rg), nominal income rates by age groups at the place of residence are determined as functions of unemployment and private consumption prices. Unemployment was determined in the quantity model. Income rates are then transformed to place of production (P) according to commuting patterns and according to the age composition of employment by sectors (j). Income is now determined implicitly as income rates multiplied by the employment, which is determined in the quantity model.

In the quantity model, income rates enter into functions for determination of employment by age group by sector (from j to g). This implicitly determines the productivity being a function of employment by age group by sector (Pj).

Figure 2. The cost-price circle – the price submodel



Note: QM: Quantity submodel; ul: unemployment; p: prices; v: income rates.

2.3. Age in the model

As indicated, age enters into the model as a factor variable. Age enters into both the factor market and the commodity market. In the factor market labour supply and demand are divided by age groups. The labour-demand function includes a substitution between different age groups in the production as well as a function for productivity by age groups which becomes a function of the composition of employment by age. On labour-supply side population by age is exogenous, whereas the labour participation rate by age depends upon the age-specific income rates.

In the commodity market the demand side is divided into private consumption and governmental consumption. Consumption rates depend upon age structure, and private consumption is small and governmental consumption is high for old age groups. Private consumption then depends on income and the age-specific consumption rates. Governmental consumption depends on population by age group and the age-specific consumption rates. From production side, age structure influences the competitiveness, because productivity and cost of production depend upon age. This influences demand (export abroad and import from abroad). Ageing involves loss of competitiveness, which in turn leads to lower demand and lower production.

3. The equations for the general interregional quantity and price model for local and urban economies in structural form

In this section, the equations of the model are examined in detail. First, the mathematical notation is presented. Then the quantity and price submodel are presented – based upon the sequential structure of the submodels following the circle in figure 1 and 2. Non-linearities in the quantity model are examined in detail.

3.1. The model – notation

The notation includes such information as variable names, subscripts, superscripts and mathematical operators. In general, the equations in the model involve tensor algebra, which is multi-dimensional matrix algebra. However, most of the notation from 2-dimensional matrix algebra can be used in tensor algebra without further explanation.

The upgrading from matrix to tensor algebra is necessary, because most variables involve one or two regional specifications. For example commuting, which is employment at the place of production and the place of residence by age group, is 3-dimensional. If also age and education and the time axis are included, the tensors will be 6-dimensional.

Variables in the model

The variables in the general interregional model are denoted in the following way:

Variables

b: Use share vector of demand
B: Use coefficient matrix of demand
D: Make coefficient matrix
G: Factor demand and composition coefficient matrices
h: Income vector
H: Income transformation coefficient matrices
J: Commuting coefficient matrix
pu: Price index vector for demand
pv: Income cost index vector
q: Employment vector
S: Shopping matrix
T: Trade coefficient matrix
v: Income rate vector
x: Gross output vector
z: Trade vector

Superscripts

P: Place of production (regional axis)
R: Place of residence (regional axis)

S: Place of commodity market (regional axis)

Subscripts

SAM-axes

j: Sector (SAM-axis)
g: Groups of factors (SAM-axis)
i: Commodity (SAM-axis)
IC: Intermediate consumption
CP: Private consumption
CO: Governmental consumption
I: Investments

Mathematical notation

': Transposed
$\circ$: Element to element multiplication
M: Capital letters for matrices (tensors)
v: Lower case letters for vectors
dM/dv: Difference for the matrix M or the vector v

In the equations 1-39 in the following two sections the general local/urban quantity model is presented, where 1-24 are the quantity submodel, whereas equations 25-39 are the price submodel.

3.2. The quantity submodel in structural form

The equations in the quantity submodel go clockwise (see figure 1) and follow the sequential structure described in section 2.2:

$$u^P_{IC,j} = b_{IC} \circ x^P_j \text{......}(1)$$
$$u^P_{IC,i} = B_{IC} u^P_{IC,j} \text{......}(2) \quad \textit{from } j \textit{ to } i$$
$$u^S_{IC,i} = S_{IC} u^P_{IC,i} \text{......}(3) \quad \textit{from } P \textit{ to } S$$
$$g^P_j = l\,(q^P_{j,g})^d \text{......}(4)$$
$$q^P_j = x \circ g^P_j \text{......}(5) \quad \textit{from } j \textit{ to } g$$
$$G = a\,(pv^P_{j,g})^b \text{......}(6)$$
$$q^P_{j,g} = G \circ q^P_j \text{......}(7) \quad \textit{from } j \textit{ to } g$$
$$q^P_g = i' q^P_{j,g} \text{......}(8) \quad \textit{from } P \textit{ to } R$$
$$q^R_g = J q^P_g \text{......}(9) \quad \textit{from } P \textit{ to } R$$
$$lq^R_g = e\,(pv^R_g)^n \text{......}(10)$$
$$l^R_g = lq^R_g \circ pop^R_g \text{......}(11)$$
$$ul^R_g = l^R_g - q^R_g \text{......}(12)$$
$$h^R_g = q^R_g \circ pv^R_g \circ v^R_g \text{......}(13)$$
$$u^R_{CP,g} = b_{CP} \circ h^R_g \circ (pu_{CP,g})^{-1} \text{......}(14)$$
$$u^R_{CP,i} = B_{CP} u_{CP,g} \text{......}(15) \quad \textit{from } g \textit{ to } i$$
$$u^S_{CP,i} = S_{CP} u^R_{CP,i} \text{......}(16) \quad \textit{from } R \textit{ to } S$$
$$u^R_{CO,g} = b_{CO} \circ pop^R_g \text{......}(17)$$
$$u^R_{CO,i} = B_{CO} u^R_{CO,g} \text{......}(18) \quad \textit{from } g \textit{ to } i$$
$$u^S_{CO,i} = S_{CO} u^R_{CO,i} \text{......}(19) \quad \textit{from } R \textit{ to } S$$
$$u^S_i = u^S_{IC,i} + u^S_{CP,i} + u^S_{CO,i} + u^S_{I,i} \text{......}(20)$$
$$z^{S,D}_i = (i - d^S_i) \circ u^S_i \text{......}(21)$$
$$z^{P,D}_i = T z^{S,D}_i \text{......}(22) \quad \textit{from } S \textit{ to } P$$
$$x^P_i = z^{P,D}_i + z^{P,F}_i \text{......}(23)$$
$$x^P_j = D x^P_i \text{......}(24) \quad \textit{from } i \textit{ to } j$$

Starting in the upper left hand corner at place of production by sector (cell Pj in figure 1) in equation 1 intermediate consumption u^P_{IC} is determined. u is demand and is a vector. The subscript IC indicates intermediate consumption. The superscript shows, that intermediate consumption is determined at the place of production P. Intermediate consumption is a function of the gross output vector x^P_j (by place of production P in fixed prices and by sector j) and the intermediate consumption share vector b_{IC}, which is intermediate consumption as share of production. In equation 2, intermediate consumption by commodity $u^P_{IC,i}$ is determined on the basis of a use matrix for intermediate consumption B_{IC} and the vector for intermediate consumption by sector from equation 1 (u^P_{IC}). In equation 3, intermediate consumption is transformed from place of production $u^P_{IC,i}$ to place of commodity market $u^S_{IC,i}$ using a shopping matrix for intermediate consumption goods (S_{IC}).

Continuing in the upper left corner (cell Pj), production generates employment q^P_j by sector j from gross output by sector and labour content g_j (equation 5). Employment content – or the inverse productivity – by sector is assumed to be a non-linear function of employment by age groups ($q^P_{j,g}$) (equation 4). A change in the composition of employment – from younger to older – will result in a change in labour content or in productivity – in this case an increase in labour content or a reduction in productivity.

In equation 7 employment by age group and by sector is determined by employment by sector vector (q^P_j) and the age by sector composition matrix (G). The share of employment by age group is assumed to be a non-linear function of the relative income rates for different employment age groups. In equation 6 the age composition matrix is function of the relative income rates by employment age group ($pv^P_{j,g}$). In equation 8 employment by age is found by summation.

Then employment by age is transformed from place of production P to place of residence R through a commuting model (from cell Pg to cell Rg, equation 9).

Labour force by age is determined by population and the participation rate (equation 11). The participation rate by age group is determined as a non-linear function of the income rate (pv^R_g) (equation 10).

Unemployment is labour force minus employment at the place of residence (equation 12). Unemployment enters into the determination of the income rate in the price model.

Income and prices on private consumption by age group are the basis for determination of private consumption place of residence (cell Rg) (equation 14). Income by age (equation 13) is found using employment (q^R_g), average income rate (v^R_g) and an income index (pv^R_g). The income cost index (pv^R_g) is determined in the price model.

In equation 14 private consumption u^R_{CP} is determined on the basis of a consumption share vector (b_{CP}) and on prices on private consumption goods (pu^R_{CP}), which in turn are determined in the price submodel.

Private consumption by commodity $u^P_{IC,i}$ is determined on the basis of a use matrix for private consumption (B_{CP}) (equation 15). Private consumption including both tourism (domestic and international) and local private consumption (cell Ri) is assigned to the place of the commodity market (cell Si) using a shopping model for local private consumption and tourism (equation 16).

Governmental consumption (cell Ri) is determined by population by age (u^R_g) and age specific consumption rates (b^R_{CO}, see equation 17). Governmental consumption by commodity $u^R_{CO,i}$ is determined on the basis of a use matrix for governmental consumption (B_{CO}) (equation 18). Through a model for shopping in local government commodities demand is transformed from place of residence to place of commodity market (cell Si) (equation 19).

Intermediate consumption together with private consumption, governmental consumption and investment constitute the total local demand for commodities (cell Si) (equation 20). Local demand is met by imports from abroad and other regions in addition to local production (equation 21). Through a trade model exports to other regions and production for the region itself are determined (equation 22). Adding export abroad, gross output by commodity is determined (cell Pi) (equation 23). Through a reverse Make matrix the cycle returns to production by sector (cell Pj) (equation 24).

3.3. The price submodel in structural form

The price model follows the sequential model described in section 2.2 and goes anticlockwise – see figure 2.

$px_i^P{}' = px_j^P{}' D$.....(25) *from j to i*

$pz_i^{P,F}{}' = px_i^P{}'$ and $pz_i^{P,D}{}' = px_i^P{}'$.....(26)

$pz_i^{S,D}{}' = pz_i^{P,D}{}' T$.....(27) *from P to S*

$pu_i^S{}' = pz_i^{S,D}{}' \circ (i - d_i^{S,F}{}') + pz_i^{S,F}{}' \circ d_i^{S,F}{}'$.....(28)

$pu_{IC,i}^P{}' = pu_i^S{}' S_{IC}$.....(29) *from S to P*

$pu_{IC,j}^P{}' = pu_{IC,i}^P{}' B_{IC}$.....(30) *from i to j*

$pu_{CP,i}^R{}' = pu_i^S{}' S_{CP}$.....(31) *from S to R*

$pu_{CP,g}^R{}' = pu_{CP,i}^R{}' B_{CP}$.....(32) *from i to g*

$dpvx_g^R{}' = (ul_g^n{}' - ul_g{}') c_g^R{}'$.....(33)

$pv_g^R{}' = p_{CP,g}^R{}' \circ b_{CP}{}' + pvx_g^R{}' \circ (i' - b_{CP}{}')'$.....(34)

$pv_g^P{}' = pv_g^R{}' J_g^{P,R}$.....(35) *From Rg to Pg*

$pve_{j,g}^P{}' = pv_g^P{}' \circ G_{j,g}^P$.....(36) *From Pg to Pj*

$pve_j^P{}' = i' pve_{g,j}^P$.....(37)

$pv_j^P{}' = pve_j^P{}' \circ (i' - jx_j^P{}') + pvx_j^P{}' \circ jx_j^P{}'$.....(38)

$px_j^P{}' = pu_{IC,j}^P{}' \circ b_{IC}{}' + pv_j^P{}' \circ (i' - b_{IC}{}')$.....(39)

Starting in the upper-left corner prices in production by sector and at place of production are transformed into a price index for production by commodities (equation 25). Here the make matrix D from the quantity model is used as weights. The price index for production by commodities is – in this simplified model – also equal to the price index for exports abroad and the price index for the domestic market (equation 26). The price index for domestic production by place of production is then transformed into a price index for demand for domestically-produced commodities at the place for commodity markets (equation 27). The trade coefficient matrix from the quantity model is used as a weight matrix. To get the price index for total demand by place of commodity market, the foreign import price index is added using the foreign import share by commodity as weights (equation 28). Again, in this simplified model the price index is the same for different types of demand. Intermediate consumption price index by place of production and by commodity is determined using the shopping matrix from the quantity model (equation 29). This in turn is transformed from price indices by commodity to price indices for intermediate consumption by sector using the use matrix for intermediate consumption from the quantity model (equation 30).

The price index for private consumption demand is transformed from place of commodity market to place of residence using the shopping matrix as weights (equation 31). Furthermore, the private consumption price index is transformed into a price index by age groups using the use matrix by age groups as weights (equation 32). This price index for private consumption together with a cost index for income not used for consumption determines the total income cost index (equation 34). The unemployment (from the quantity model) enters into the equation for determination of the cost index for the income, which is not consumed (equation 33). Here the change in income cost index is assumed to depend upon the difference between unemployment and the natural rate of unemployment by age group. In equation 35, the cost index for income by place of production is derived using the commuting coefficients matrix from the quantity model. Further, a cost index for income by age group and sector is derived in equations 36 using the labour content matrix from the quantity model. A cost index for total income at place of production is found in equation 38 by adding the cost index for the endogenously determined income with a cost index for the exogenously determined factor income.

In equation 39 the production price index is determined using a simple adding-up principle on intermediate consumption price index and income index using the cost shares as weights.

3.4. Linking the quantity and the price model – Non-linearities in the quantity model

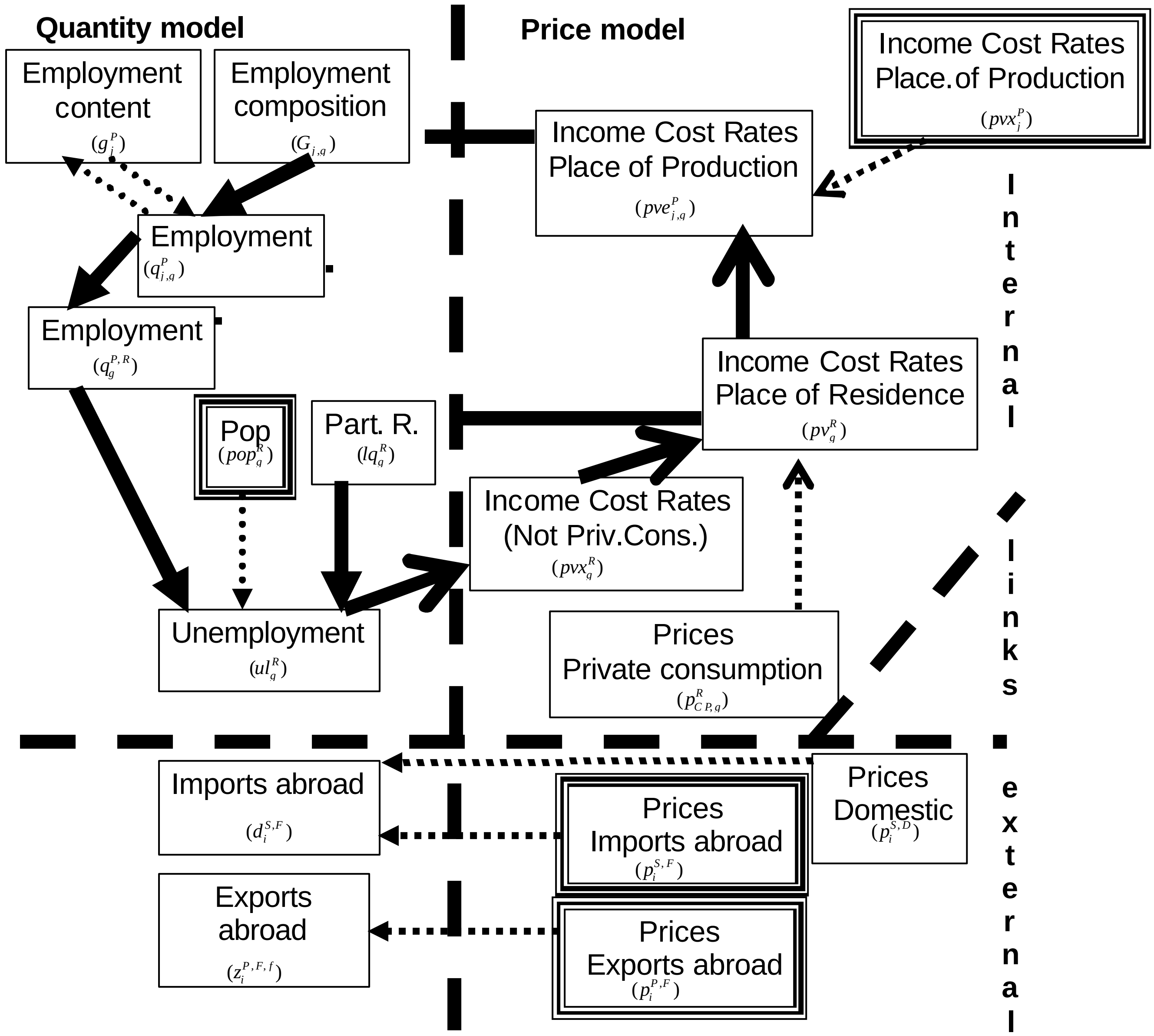
The submodels are linked together such that prices influence quantities and quantities influence prices. The links between the two models can be illustrated in figure 3.

The links are divided into internal links and external links. Internal links are defined as links, which form a simultaneous system covering both models, whereas external links are links where the links are non-simultaneous, where an endogenous variable, which is an exogenous explaining variable in the other submodel, does not enter as explanatory variable in the submodel itself.

The upper part of the diagram shows – in bold – two internal links in the model: First, in the quantity model (equation 10) – shown as the inner bold circle – the labour participation rates by age group and by place of residence depend upon the income rates, which are determined in the price model (equation 34). Labour force is a function of the population and of the labour-participation rates, which in turn together with the employment determine the unemployment (the dashed line in the diagram – see equation 12). Unemployment (the quantity model) together with private consumption prices (the price model) explain the income rates in the price model (equation 30), forming a simultaneous block.

Second, in the quantity model – shown as the outer bold circle in figure 3 – income rates (price model) determine the age composition of employment (equation 5). The age composition explains the labour content (inverse productivity – see equation 6), which – after a number of transformations (equations 7 to 9) – enter into the determination of employment and unemployment by place of residence (the dashed line in the diagram). Unemployment together with private consumption prices enter into the income rate equation in the price model (equation 34). Income rates by place of residence are in the price model transformed from the place of production using employment and commuting variables from the quantity model (the dashed line in the diagram – see equations 35 to 38) forming another simultaneous block covering both submodels.

Figure 3. Links between the quantity and the price models



External links have not been included in the presentation of the equations in the model. In external links exogenous variables in the first submodel is explained by an endogenous variable in the second submodel. In the model presented in this paper, export abroad is the exogenous variable in the quantity (first) model, whereas the price on export abroad is an endogenous variable in the price (second) model. Another example, which has not been included in the model, is the foreign import share, which in the quantity (first) model depends upon foreign import prices compared with domestic prices, which is determined in the price (second) model.

4. The solution to the model

4.1. The model in changes

When we set up a model like the one in this paper, a choice between modelling in absolute variables or in changes arises. The advantage of modelling in absolute variables is that an exact solution of the model can be arrived at. The disadvantage is that it is often necessary to assume linear functions in order to solve the model. The advantage of modelling in changes is that non-linearities can be allowed. Modelling in changes makes all equations linear in these changes. In addition, when modelling in changes the solutions to the model have an interpretation as multipliers. The disadvantage of modelling in changes is that an exact solution of the model is not possible because the model is non-linear. In this paper we choose to model in changes and, thereby, we extend the work by Madsen (2007a & 2007b) to allow for non-linear functions.

In the appendix, the quantity and the price models have been formulated in changes. This is done by differentiating all single equations in both submodels. The solution to the model formulated in changes can now be derived explicitly.

4.2. The solution to the model

The quantity and the price models are solved separately, both by insertion.

In the quantity model the model is solved for unemployment. This involves solutions for employment and for the labour force. The *solution for the labour force* is straightforward involving insertion of equation A.9 into equation A.12, A.10 into A.11 and into A.12. The *solution for the employment* involves a *solution for gross output* and, on the basis of this, *a solution for employment*.

In the *solution for gross output* the intermediate consumption chain is inserted from equation A.1 into equation A.2 and further into A.3 and then into equation A.20. The income, price and *private consumption* chain is then inserted, which involves insertion of equations A.4 to A.9 and further equations A.13 to A.16 and after that into equation A.20. Then, *governmental consumption* in equation A.17 is inserted into A.18, A.19 and then into A.20. Finally, equation A.20 is inserted into A.21, into A.22, into A.23 and finally into A.24.

In *the solution for employment*, which is a part of the solution to the private consumption, two steps of insertion are involved: First, equation A.6 is inserted into A.7, A.4 into A.5 and A.5 into A.7. Then the solution to this subsystem resulting in equation A.7 is inserted into equation A.8 and further into equation A.9 etc.

This process of insertions gives the following result:

$$
\begin{aligned}
dul_g^R = lq_g^R \circ dpop_g^R - Ji'\left[i' - G \circ x \circ ld\,(q_{j,g}^P)^{d-1}\right]^{-1} G \circ g \circ
&\left[
\begin{bmatrix}
i - DT(i-d_i^S) \circ S_{IC} B_{IC} b_{IC} \\
- DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ (pu_{CP,g})^{-1} \circ pv_g^R \circ v_g^R \circ Ji'\left[i' - G \circ x \circ ld\,(q_{j,g}^P)^{d-1}\right]^{-1} G \circ g
\end{bmatrix}^{-1}
\begin{bmatrix}
+DT(i-d_i^S) \circ S_{CO} B_{CO} b_{CO}\, dpop_g^R \\
+DT(i-d_i^S) \circ du_{I,i}^S \\
+DT(i-dd_i^S) \circ u_i^S \\
\\
+Ddz_i^{P,F} \\
+DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ (pu_{CP,g})^{-1} \circ pv_g^R \circ v_g^R \circ Ji'\left[i' - G \circ x \circ ld\,(q_{j,g}^P)^{d-1}\right]^{-1}
\begin{bmatrix}
q_j^P \circ ab\,(pv_{j,g}^P)^{b-1} dpv_{j,g}^P \\
+q_j^P \circ da\,(pv_{j,g}^P)^{b} \\
+G \circ x \circ dl\,(q_{j,g}^P)^{d}
\end{bmatrix} \\
+DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ (pu_{CP,g})^{-1} \circ q_g^R \circ py_g^R \circ dv_g^R \\
+DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ (pu_{CP,g})^{-1} \circ q_g^R \circ dpv_g^R \circ v_g^R \\
-DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ h_g^R \circ (pu_{CP,g})^{-2} dpu_{CP,g} \\
\\
+DT(i-d_i^S) \circ S_{IC} B_{IC} db_{IC} \circ x_j \\
+DT(i-d_i^S) \circ S_{IC} dB_{IC} u_{IC,j}^P \\
+DT(i-d_i^S) \circ dS_{IC} u_{IC,i}^P \\
+DT(i-d_i^S) \circ S_{CP} B_{CP} b_{CP} \circ (pu_{CP,g})^{-1} \circ pv_g^R \circ v_g^R \circ dJq_g^P \\
+DT(i-d_i^S) \circ S_{CP} B_{CP} db_{CP} \circ h_g^R \circ (pu_{CP,g})^{-1} \\
+DT(i-d_i^S) \circ S_{CP} dB_{CP} u_{CP,g} \\
+DT(i-d_i^S) \circ dS_{CP} u_{CP,i}^R \\
+DT(i-d_i^S) \circ S_{CO} B_{CO} db_{CO}\, pop_g^R \\
+DT(i-d_i^S) \circ S_{CO} dB_{CO} u_{CO,g}^R \\
+DT(i-d_i^S) \circ dS_{CO} u_{CO,i}^R \\
+DdTz_i^{S,D} \\
+dDx_i^P
\end{bmatrix}
\right] \\
&+ de\,(pv_g^R)^n \circ pop_g^R \\
&+ en\,(pv_g^R)^{n-1} dpv_g^R \circ pop_g^R \text{ ....(40)}
\end{aligned}
$$

The price model is solved by straightforward insertion:

Equation A.25 is inserted into equation A.26, then into equation A.27, and finally into equation A.28. Then the insertion line is split into two sublines: The intermediate consumption line involves insertion into equation A.29 and A.30, and finally into equation A.39. The private consumption price-income line involved insertion of equation A.31 further into equations A.32, A.33, A.34 etc. ending inserting into equation A.39. This gives the following solution for the price model:

$$dpx_j' = \begin{bmatrix} i' - DT \circ (i - d_i^{S,F}{}')S_{IC}B_{IC} \circ b_{IC}{}' \\ -DT \circ (i - d_i^{S,F}{}')S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \end{bmatrix}^{-1}$$

$$\begin{bmatrix} dpz_i^{S,F}{}' \circ d_i^{S,F}{}' S_{IC}B_{IC} \circ b_{IC}{}' \\ +dpz_i^{S,F}{}' \circ d_i^{S,F}{}' S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ \\ -dul_g{}' c_g^{R}{}' \circ (i' - b_{CP}{}')' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ \\ +px_j{}' dDT \circ (i - d_i^{S,F}{}')S_{IC}B_{IC} \circ b_{IC}{}' \\ +pz_i^{P,D}{}' dT \circ (i - d_i^{S,F}{}')S_{IC}B_{IC} \circ b_{IC}{}' \\ +pz_i^{S,D}{}' \circ (i - dd_i^{S,F}{}')S_{IC}B_{IC} \circ b_{IC}{}' \\ +pz_i^{S,F}{}' \circ dd_i^{S,F}{}' S_{IC}B_{IC} \circ b_{IC}{}' \\ +pu_i^{S}{}' dS_{IC}B_{IC} \circ b_{IC}{}' \\ +pu_{IC,i}^{P}{}' dB_{IC} \circ b_{IC}{}' \\ \\ +px_j{}' dDT \circ (i - d_i^{S,F}{}')S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pz_i^{P,D}{}' dT \circ (i - d_i^{S,F}{}')S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pz_i^{S,D}{}' \circ (i - dd_i^{S,F}{}')S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pz_i^{S,F}{}' \circ dd_i^{S,F}{}' S_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pu_i^{S}{}' dS_{CP}B_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pu_{CP,i}^{R}{}' dB_{BC} \circ b_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ -ul_g{}' d\,c_g^{R}{}' \circ (i' - b_{CP}{}')' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pu_{CP,g}^{R}{}' \circ db_{CP}{}' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pvx_g^{R}{}' \circ (i' - db_{CP}{}')' J_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pv_g^{R}{}' dJ_g^{P,R} \circ i' G_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pv_g^{P}{}' \circ dG_{j,g}^{P} \circ (i' - jx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +dpvx_j^{P}{}' \circ jx_j^{P}{}' \circ (i' - b_{IC}{}') \\ +pve_j^{P}{}' \circ (i' - djx_j^{P}{}') \circ (i' - b_{IC}{}') \\ +pvx_j^{P}{}' \circ djx_j^{P}{}' \circ (i' - b_{IC}{}') \\ +pu_{IC,j}^{P}{}' \circ db_{IC}{}' + pv_j^{P}{}' \circ (i' - db_{IC}{}') \end{bmatrix} \text{............(41)}$$

5. Interpretation of the solution

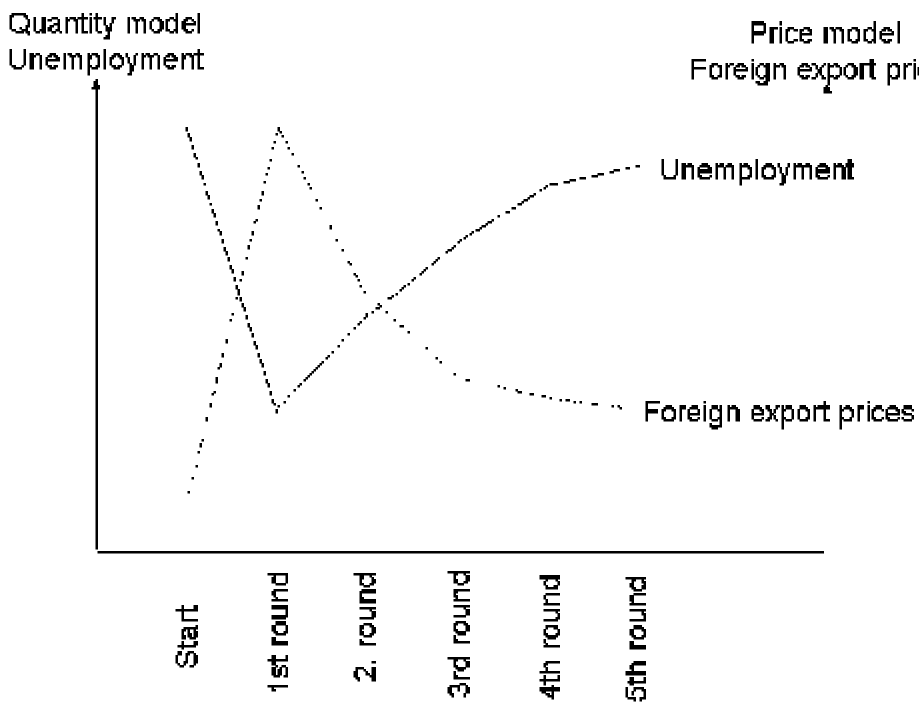
The model and its solutions can now be applied for the analysis of impacts of demographic changes in the local economy. In section 5.1 the impacts are traced through the sequence of calculations starting in the quantity submodel, including both the direct and derived effects (solution equation 40). This is followed by examination of the solution to the price model, involving the direct and derived effects in the price model (solution equation 41). Then a second round solution is obtained involving revised direct and derived effects in the quantity submodel (solution equation 40 recalculated), which is followed by the direct and derived in the price submodel (solution equation 41 recalculated). After a number of calculation rounds involving both submodels the model will converge in a simultaneous solution.

Section 5.2 examines how the impacts on different types of regions depend upon the structure of economic interaction between regions, where the impacts propagate to other regions depending upon the leakages in the local economy. If the economy is very open, the multiplier will be low because leakages in the local economy reduce the impacts, leakages being the trade, the commuting and the shopping, and vice versa for closed local economies multipliers are high.

5.1 Impacts of demographic changes on unemployment and export prices

Starting in the quantity model, the labour supply (l_g^R) decreases as a consequence of the ageing process. This is caused by ageing of population, which leads to retirement. From equation 40 labour force (l_g^R) change, because the number of old people in the population (pop_g^R) increase relatively to the number of young people assuming unchanged age-specific labour participation rates (lq_g^R).

Figure 4. Changes in unemployment and export prices in the iterative steps in the simultaneous solution to the quantity and price models



From equation 40 it can be seen that employment – at least in the short run – will not change due to changes in population, except for minor adjustments in governmental consumption and private consumption. Adjustments in governmental consumption will lead to minor increases in employment, because average governmental consumption for old people can be expected to be higher than for young people, which in turn leads to higher demand, production and employment. On the other hand, private consumption share will decrease as it can be assumed, that the share will decrease due to lower consumption rate with increasing age. The net effect will be small changes in total consumption rate.

The net effect of ageing is therefore that, ceteris paribus, unemployment – in the short run – will decrease because of the ageing process. Figure 4 illustrates the changes in unemployment in the 1st round calculation in the quantity model (the minimum point on the non-dotted curve).

Although, the ageing process does not involve employment reduction, the structural shift from productive sectors to increasing production of services for the elder population should be added. This specialisation increases the vulnerability of age-dependent regions and local economies, because the export base is downscaled.

Now, moving to the price model, decreases in unemployment (dul_g^R) will lead to higher nominal income rates and in turn to higher prices on production (see equation 41). This will – at least in the short run – leave the real domestic income rate unchanged. But the net effect of ageing will be higher producer prices, which in turn have impacts on prices for exports abroad and domestic prices compared with prices for import from abroad. The initial increase in the foreign export prices is illustrated in Figure 4 (the maximum point on the dotted curve). In the quantity model reduced demand from lower foreign exports and higher imports from abroad modify the reduction in unemployment, because employment decreases. This increase in 2nd round calculation of the unemployment is illustrated in figure 4. This in turn will lead to a decrease in export prices, which is illustrated in figure 4 as the result of the 2nd round calculation.

After a number of calculation rounds the unemployment and prices converge to a new equilibrium, where unemployment is back at the original level and relative export prices are at a higher level than the initial level of prices. As a consequence, exports decrease and import increases and employment will go down.

This process will lead to changes in both real income rate and employment, together having a negative net effect on total income. Real income rate can be assumed to be unchanged because both the nominal income rates and the prices are expected to increase, leaving the real income rates unchanged. Employment will decrease, because the labour force will decrease markedly. With a reduction in employment the unemployment will be unchanged. Net real income will go down because employment times real income rates will decrease.

5.2. Regional impacts of ageing

Using the simultaneous solution to the two submodels, it can be seen that the regional impacts of a given ageing process depend upon the leakages in the local economy. The more open the economy, the less the negative impacts will be on the local area itself, exporting the negative impacts to other regions and the rest of the world. For closed economies, the negative impacts will be multiplied, because most impacts are in the local area itself. Taking trade as an example, the negative impacts of a reduction in foreign exports and increase in import from abroad on the local area, where the ageing takes place, will be smaller the higher the share of interregional and international imports.

This truncation in the negative impacts from ageing due to leakages in the local economy applies both in the quantity model and the price model. In the quantity model, the reduction in production due to reductions in demand will be smaller, the higher the import share, the higher out-commuting and the higher the shopping outside the local area. In the price model, similarly the increases in prices due to income increases in the local area will be smaller the more open economy. The higher the share of export abroad and exports to other regions, the smaller the spill-over of cost increases from rising income will be. The higher the sale of commodities to consumers from outside the local area, the more consumers from outside will bear the burden from increasing consumer prices. And the higher the share of the employed, who resides outside the local area, the more the negative impacts from rising income cost on production will be exported to other regions.

This analysis of the multipliers in the local economies does not apply to trade alone, but to all types of interactions in the model, such as shopping and commuting. Taking the multipliers in equations 40 and 41 as the point of departure the leakages, and the impacts on different types of local economies, are the following:

From Table 1, 7 types of local areas have been defined: Metropolitan areas divided into the centre, residential suburbs and production suburbs, urban centres, divided into urban and suburban areas, and finally rural areas, divided into areas which are connected or are not connected to urban centres.

For shopping in intermediate consumption goods (column 1) commodities are to some degree bought outside the area (indicated by “Mid” in row 1). For the centre of metropolitan areas, this share can be assumed to be lower because wholesaling activities can be assumed to be concentrated in metropolitan areas. Therefore the intra-shopping is relatively high, marked with a “++” in row 2. For suburban areas, which are specialised in production activities probably a number of wholesale firms might be located, although the probability is much lower than for metropolitan centre areas. Therefore, a ”+” has been indicated in row 3. For residential metropolitan areas no wholesale activities can be expected, and therefore an “--“ is shown in row 4. For urban centres, wholesale functions are found, but not as frequently as in metropolitan areas, giving a “+” in row 5. For rural areas wholesale activities or firms supplying intermediate consumptions goods for rural firms are underrepresented leading to a “--“ in rows 6 and 7.

In column 2 the leakages originating from commuting are shown. In general, leakages working through income formation are substantial. Leakages are smaller in the centre of the metropolitan area, because relative fewer have jobs outside the area, whereas residential areas have relative more jobs outside the area. Especially, for rural areas disconnected from urban centres commuting out of the area is very limited.

In column 3 the leakages from shopping is shown and is in general being at medium level. Leakages are smaller for urban metropolitan areas, higher for residential areas and low for rural areas disconnected from urban centres.

In column 4 leakages for shopping in governmental consumption are examined, being at a low level, because almost all individual governmental consumption is produced and consumed at the local level. General governmental consumption and specific types of individual governmental consumption such as hospitals and educational services are supplied outside the local area. From a regional point of view, because general governmental consumption and the specific individual governmental consumption are geographically concentrated in metropolitan areas, leakages are lowest in the centre of the metropolitan area and decreasing the longer away from the city centres.

Table 1. Geographical leakages and typology for local economies

Type of region		Shopping in intermediate consumption goods in same region	Commuting to same region	Shopping in private consumption in same region	Shopping in governmental consumption in the same region	Domestic supply / local demand	Local supply / domestic sales	Total multiplier
Mathematical representation		$\frac{u^{P,S}_{IC,i} \Vert P=S}{u^{P}_{IC,i}}$	$\frac{q^{P,R}_{g} \Vert P=R}{q^{P}_{g}}$	$\frac{u^{R,S}_{CP,i} \Vert R=S}{u^{R}_{CP,i}}$	$\frac{u^{R,S}_{CO,i} \Vert R=S}{u^{R}_{CO,i}}$	$\frac{z^{D}_{i} \Vert S=P}{u^{S}_{i}}$	$\frac{z^{S,P}_{i} \Vert S=P}{u^{S,D}_{i}}$	
National average		Mid	High	Mid	Low	Mid	Low	
Metropolitan area:	Centre	++	++	++	+	0	--	High
	Residential suburbs	--	--	--	-	0	--	Very low
	Production suburbs	+	++	-	-	0	++	High
Urban centres	Centre	+	+	+	+	0	+	High
	Suburbs	-	--	-	-	0	-	Very low
Rural areas	Connected to urban centres	--	--	--	-	0	--	Very low
	Disconnected from urban centres	--	++	++	0	0	--	Mid

In column 5 and 6 the trade leakages are examined. In general, these leakages are much higher than leakages for shopping and commuting. Relatively, leakages are lowest in productive areas such as urban centres and production suburbs and highest in metropolitan centres and in rural areas.

Concluding, the total multiplier (see column 7), both in terms of the quantity model and the price model is highest in productive suburban areas, where the leakages are smallest, especially in trade, whereas multipliers are lowest in residential areas, where leakages are highest both in trade and in commuting and shopping. The metropolitan centre has below average leakages, being very low in commuting and shopping leakages and at medium level in trade. The multiplier in rural areas, with connection to urban centres will be very low, whereas leakages in rural areas will be medium in rural areas where leakages are small in commuting and shopping, but high in trade.

5.3. Specification of the model

The basic model, which has been presented above, represents specific equilibrium and behavioural mechanism, reflecting a short time horizon and equilibrium in the commodity market, but not in the labour market. Even though these seemingly restrictive characteristics the model can be adjusted in order to reflect other time horizons and behavioural mechanism. In relation to the demographic problem the following characteristics of the basic model – and relevant extensions – seem important:

Three types of regions with different functions in the economy are represented in the model: The region itself, other regions and regions abroad. In the case of Denmark, it could be Danish municipalities, Denmark and countries outside Denmark. In the case of the European Union, it could be the regions, the EU and the Rest of the World. The regional structure, which the model should reflect, is of course important for decisions concerning model structure. The division into three types of region seems relevant and important from a policy and a behaviour point of view.

In the basic model there is not full treatment of interaction: Only trade involves both interregional and international trade, whereas commuting and shopping only include interregional interaction, whereas international commuting and shopping have been excluded from the model. As internationalization evolves, it is relevant to extend the model to include international commuting and shopping/tourism. In the formulation of the general interregional quantity model (Madsen 2007a) and the general interregional price model (Madsen 2007b) all types of interaction, international as well as interregional have been included into the model.

In the basic model, regional wealth, interest payments and balance of payment – both the international and the interregional – do not enter. The regional wealth, interest and balance of payment issues involve the time horizon, where an extension of the model with wealth and interest payments will include the medium or even long run by taking into account the adjustments in the regional economy to the reduction in wealth, derived interest payments, which regions with ageing problems face. Another alternative would be to assume flexible exchange rates, but this only undertakes the international balance of a payment adjustment process.

The basic model implicitly assumes that the demographic development only originates from the region itself. Interregional as well as international migration should be added, if medium or long-term adjustments are to be included. Migration will change the population and the labour force, which will have an impact on unemployment and income rates, which in turn will have an impact on employment and participation rates. Although modelling of migration behaviour is complex, inclusion of impacts of migration is straightforward. The change in population can simply be interpreted as including migration plus population changes from the region itself.

6. Conclusion

In this paper, the impacts of the population ageing process on the regional and local economy are discussed in the framework of the general interregional quantity and price models (Madsen 2007a & 2007b). The ageing process identifies decreasing participation rates for the labour force and decreasing productivity in production. The negative impacts depend upon the direct changes in population by age group, the direct labour market effects of population changes and the derived or multiplier effects from these changes.

In the quantity submodel the composition of labour force is determined by relative income rates. Participation rates, productivity and the composition of employment are assumed to be iso-elastic. To evaluate the impacts of ageing of such iso-elastic behaviour the general interregional quantity and price submodels have been formulated in changes. In this way, the model can be used to evaluate effects of changes in the locale economies from the ageing of population assuming more consistent behaviour than in the pure linear models. The quantity and price submodels have been solved separately, and the simultaneous solution is discussed. The multipliers of the model are evaluated theoretically, using plausible assumption about leakages in the local economy. Based upon these theoretical and empirical arguments multipliers for the centre and for the production suburbs in metropolitan areas and for rural areas disconnected from urban areas seems to have multipliers above average, whereas multipliers for the residential areas, both in metropolitan and urban areas have below average multipliers. Multipliers involve both the conventional quantity model multipliers as well as the multipliers derived from the price model.

Appendix

The general interregional quantity model in growth form

$$du_{IC}^{P} = b_{IC} \circ dx_j + db_{IC} \circ x_j \text{..........} (A.1)$$

$$du_{IC,i}^{P} = B_{IC} du_{IC}^{P} + dB_{IC} u_{IC}^{P} \text{..........} (A.2) \quad \textit{from j to i}$$

$$du_{IC,i}^{S} = S_{IC} du_{IC,i}^{P} + dS_{IC} u_{IC,i}^{P} \text{..........} (A.3) \quad \textit{from P to S}$$

$$dg = d\,l\,(q_{j,g}^{P})^{d} + l\,d\,(q_{j,g}^{P})^{d-1} dq_{j,g}^{P} \text{..........} (A.4)$$

$$dq_{j}^{P} = x_j \circ dg + dx_j \circ g \text{..........} (A.5) \quad \textit{from j to g}$$

$$dG = da\,(pv_{j,g}^{P})^{b} + a\,b\,(pv_{j,g}^{P})^{b-1} dpv_{j,g}^{P} \text{..........} (A.6)$$

$$dq_{j,g}^{P} = G \circ dq_{j}^{P} + dG \circ q_{j}^{P} \text{..........} (A.7) \quad \textit{from j to g}$$

$$dq_{g}^{P} = i' dq_{j,g}^{P} \text{..........} (A.8) \quad \textit{from P to R}$$

$$dq_{g}^{R} = J dq_{g}^{P} + dJ q_{g}^{P} \text{..........} (A.9) \quad \textit{from P to R}$$

$$dlq_{g}^{R} = en\,(pv_{g}^{R})^{n-1} dpv_{g}^{R} + de\,(pv_{g}^{R})^{n} \text{..........} (A.10)$$

$$dl_{g}^{R} = lq_{g}^{R} \circ dpop_{g}^{R} + dlq_{g}^{R} \circ pop_{g}^{R} \text{..........} (A.11)$$

$$dul_{g}^{R} = dl_{g}^{R} - dq_{g}^{R} \text{..........} (A.12)$$

$$dh_{g}^{R} = dq_{g}^{R} \circ pv_{g}^{R} \circ v_{g}^{R} + q_{g}^{R} \circ dpv_{g}^{R} \circ v_{g}^{R} + q_{g}^{R} \circ pv_{g}^{R} \circ dv_{g}^{R} \text{..........} (A.13)$$

$$du_{CP,g}^{R} = b_{CP} \circ dh_{g}^{R} \circ (pu_{CP,g})^{-1} + db_{CP} \circ h_{g}^{R} \circ (pu_{CP,g})^{-1} - b_{CP} \circ h_{g}^{R} \circ (pu_{CP,g})^{-2} dpu_{CP,g} \text{..........} (A.14)$$

$$du_{CP,i}^{R} = B_{CP} du_{CP,g} + dB_{CP} u_{CP,g} \text{..........} (A.15) \quad \textit{from g to i}$$

$$du_{CP,i}^{S} = S_{CP} du_{CP,i}^{R} + dS_{CP} u_{CP,i}^{R} \text{..........} (A.16) \quad \textit{from R to S}$$

$$du_{CO,g}^{R} = b_{CO} dpop_{g}^{R} + db_{CO}\, pop_{g}^{R} \text{..........} (A.17)$$

$$du_{CO,i}^{R} = B_{CO} du_{CO,g}^{R} + dB_{CO} u_{CO,g}^{R} \text{..........} (A.18) \quad \textit{from g to i}$$

$$du_{CO,i}^{S} = S_{CO} du_{CO,i}^{R} + dS_{CO} u_{CO,i}^{R} \text{..........} (A.19) \quad \textit{from R to S}$$

$$du_{i}^{S} = du_{IC,i}^{S} + du_{CP,i}^{S} + du_{CO,i}^{S} + du_{I,i}^{S} \text{..........} (A.20)$$

$$dz_{i}^{S,D} = (i - d_{i}^{S}) \circ du_{i}^{S} + (i - dd_{i}^{S}) \circ u_{i}^{S} \text{..........} (A.21)$$

$$dz_{i}^{P,D} = T dz_{i}^{S,D} + dT z_{i}^{S,D} \text{..........} (A.22) \quad \textit{from S to P}$$

$$dx_{i}^{P} = dz_{i}^{P,D} + dz_{i}^{P,F} \text{..........} (A.23)$$

$$dx_j = D dx_{i}^{P} + dD x_{i}^{P} \text{..........} (A.24) \quad \textit{from i to j}$$

$$dpx_i^P{}' = dpx_j{}'D + px_j{}'dD \text{..(A.25)} \quad \textit{from } j \textit{ to } i$$

$$dpz_i^{P,D}{}' = dpx_i^P{}' \text{...(A.26)}$$

$$dpz_i^{S,D}{}' = dpz_i^{P,D}{}'T + pz_i^{P,D}{}'dT \text{...(A.27)} \quad \textit{from } P \textit{ to } S$$

$$dpu_i^S{}' = dpz_i^{S,D}{}' \circ (i - d_i^{S,F}{}') + dpz_i^{S,F}{}' \circ d_i^{S,F}{}'$$
$$+ pz_i^{S,D}{}' \circ (i - dd_i^{S,F}{}') + pz_i^{S,F}{}' \circ dd_i^{S,F}{}' \text{........................(A.28)}$$

$$dpu_{IC,i}^P{}' = dpu_i^S{}'S_{IC} + pu_i^S{}'dS_{IC} \text{...(A.29)} \quad \textit{from } S \textit{ to } P$$

$$dpu_{IC,j}^P{}' = dpu_{IC,i}^P{}'B_{IC} + pu_{IC,i}^P{}'dB_{IC} \text{......................................(A.30)} \quad \textit{from } i \textit{ to } j$$

$$dpu_{CP,i}^R{}' = dpu_i^S{}'S_{CP} + pu_i^S{}'dS_{CP} \text{...(A.31)} \quad \textit{from } S \textit{ to } R$$

$$dpu_{CP,g}^R{}' = dpu_{CP,i}^R{}'B_{CP} + pu_{CP,i}^R{}'dB_{BC} \text{...................................(A.32)} \quad \textit{from } i \textit{ to } g$$

$$dpvx_g^R{}' = (dul_g^n{}' - dul_g{}')c_g^R{}' + (ul_g^n{}' - ul_g{}')dc_g^R{}' \text{....................(A.33)}$$

$$dpv_g^R{}' = dpu_{CP,g}^R{}' \circ b_{CP}{}' + dpvx_g^R{}' \circ (i' - b_{CP}{}')'$$
$$+ pu_{CP,g}^R{}' \circ db_{CP}{}' + pvx_g^R{}' \circ (i' - db_{CP}{}')' \text{..........................(A.34)}$$

$$dpv_g^P{}' = dpv_g^R{}'J_g^{P,R} + pv_g^R{}'dJ_g^{P,R} \text{...(A.35)} \quad \textit{From } Rg \textit{ to } Pg$$

$$dpve_{g,j}^P{}' = dpv_g^P{}' \circ G_{j,g}^P + pv_g^P{}' \circ dG_{j,g}^P \text{....................................(A.36)} \quad \textit{From } Pg \textit{ to } Pj$$

$$dpve_j^P{}' = i'dpve_{g,j}^P \text{..(A.37)}$$

$$dpv_j^P{}' = dpve_j^P{}' \circ (i' - jx_j^P{}') + dpvx_j^P{}' \circ jx_j^P{}'$$
$$+ pve_j^P{}' \circ (i' - djx_j^P{}') + pvx_j^P{}' \circ djx_j^P{}' \text{...........................(A.38)}$$

$$dpx_j{}' = dpu_{IC,j}^P{}' \circ b_{IC}{}' + dpv_j^P{}' \circ (i' - b_{IC}{}')$$
$$+ pu_{IC,j}^P{}' \circ db_{IC}{}' + pv_j^P{}' \circ (i' - db_{IC}{}') \text{...............................(A.39)}$$

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Section 7:

Theoretical and operational issues in sub-regional economic modelling, illustrated through the development and application of the LINE model

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Theoretical and operational issues in sub-regional economic modelling, illustrated through the development and application of the LINE model

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Abstract

Regional economic models have traditionally focussed on the market for goods and services and have usually been input–output based, utilising large regional units. Sub-regional or local economic modelling has, on the other hand, traditionally been concerned with specific, isolated (and often urban) economic phenomena, such as labour markets, commuting, tourism and shopping. Theory and models linking the regional economy and activities at sub-regional level are weakly developed, even though the links between these two levels are fundamental in understanding basic mechanisms in the spatial economy at the sub-regional level and, therefore, ultimately also at the regional level. This article examines theoretically the nature of these links through the perspective of a recently developed disaggregated sub-regional general equilibrium economic model, LINE, and discusses related operational problems and strategies. A concrete application of the model to analyse the effects of changing transport costs and bridge tolls in Denmark on economic activity at sub-regional level is presented, illustrating the issues raised.

JEL classifications: R12; R13; R41

Keywords: Sub-regional economic modelling; Regional and interregional; CGE models; Input-output; SAM

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1. Introduction

Traditionally, there has been a clear distinction between modelling at regional and at sub-regional levels. In regional models the main focus has been on markets for goods and services, whilst sub-regional or local models have focussed on such fields as labour markets, including commuting, and shopping trips and patterns. The geographical unit used in regional models has usually been based on administrative definitions related to regional government and occasionally, labour market catchment areas rather than smaller sub-regional units. One important consequence of choice of this spatial level is that activities such as commuting between areal units and shopping trips crossing area boundaries are limited in importance and volume, and frequently are not modelled.

In contrast, local or sub-regional models, dealing with such questions as commuting and shopping, have tended to regard production and employment, at least in basic sectors, as determined outside the model. In recent decades, however, a number of new social and economic trends have emerged, which have made reconsideration of the local or sub-regional level necessary (Coombes et al., 1988). Labour markets and average commuting distances have grown substantially rendering assumptions about co-location of residence and employment questionable. An increasing variety of products have meant that for the average firm, a growing share of its production becomes basic, in the sense that an increasingly larger share of its production is sold outside the region. Long-distance shopping, based on the car, has increased in importance, as has long-distance tourism, both national and international. Finally, there has been a growth in demands from local (typically urban) and sub-regional policy makers for scientifically founded studies to be used to formulate policy for local areas. The present wave of interest in industrial clusters as a policy instrument is but one example (Gordon and McCann, 2000).

These changes lie behind the development of a local economic model, LINE, that integrates markets for goods and services and for factors of production and also includes activities such as commuting, shopping, tourism as well as trade in goods and services. A central principle in the model construction has been to ensure a high degree of flexibility both in terms of aggregation of basic analytical categories including the areal units used and possibilities for elimination of categories of actors, permitting a wide range of problems to be addressed. This paper presents this sub-regional model, together with an application to a concrete spatial economic problem.

2. Sub-regional macroeconomic modelling

In the last 10 years or so there has been increasing focus on local economic problems and interactions between different types of sub-regions, for example the urban fringe and the CBD (Renkow and Hoover, 2001; Stanback, 1991; Cheshire, 1993). Growing interest in the role of externalities and spillover effects (Glaeser et al., 1992; Henderson et al., 1995; Acs et al., 1994; Audretsch and Feldman, 1996; Parr et al., 2002), which have an inherently local or sub-regional dimension, has also contributed to this focus. In addition, demands from policymakers concerning local economic data and analysis have grown, for example, in relation to past, present and future patterns of income generation (Madsen and Jensen-Butler, 2002a). This has occurred at a time when the modelling tradition, in broad terms, has two principal components.

On the one hand, there is the input–output based modelling tradition, where the focus is on regional and interregional equilibria in the commodity market (Oosterhaven, 1981; Polenske, 1980; Issaev et al., 1982; Jensen-Butler and Madsen, 1996). One characteristic of these models is the implicit assumption that place (region) of residence and place of production (employment) are the same. Likewise, place of residence and place of demand, both for final and for intermediate consumption, are generally assumed to be the same. As regions were usually defined as large areal units, problems arising from violation of these assumptions were treated as minor, which is, however, not necessarily the case if a metropolitan region is defined. One of the few authors who, on a number of occasions, has pointed out the potentially damaging effects of these seemingly innocent assumptions is Cheshire (1993, 1997) and Cheshire and Hay (1989). A further characteristic of this approach is that models, until recently, have usually been industry-based, neglecting other types of flows, such as to monetary flows to factors of production and institutions (households, firms and government). This approach, whilst general, does not usually incorporate the effects of prices on behaviour or the effects of externalities on production.

On the other hand, there is the tradition of urban land use modelling, where, in spatial terms, small areas are the common geographical unit chosen, and surrounding areas are treated as exogenous. The approach here is intrinsically sub-regional. There are numerous approaches to aspects of the relationship between land use and interaction, for example, commuting models for travel between place of residence and place of production (Wang, 2001; Renkow and Hoover, 2001; Casado-Diaz, 2000; Gitelsen and Thorsen, 2002; Andersen, 2002a; Artis et al., 2000). Another sub-regional interaction model is the set of shopping models for travel between place of residence and place of demand, which, in their early formulations, were usually based on the gravity model (Lakshmanan and Hansen, 1965). Recently, shopping models have been developed to include the impact of supply side changes on consumer spatial behaviour (Guy, 1996; Munroe, 2001) and also the impact of the internet (Rao, 1999; Szymanski and Hine, 2000). However, there is also a return to gravity model formulations in more recent work. For example, Baker (2000) models gravity coefficients in simultaneous spatial and temporal contexts and Cadwallader (1995) examines interaction effects among constituent spatial attributes on the consumer's utility function, in the context of log–linear models, again with relationships to gravity model formulations.

These interaction models were usually developed as stand-alone models, typically focussing on one type of interaction, and sometimes employing relatively detailed institutional categories, for example, household types (see Wilson et al., 1969). However, there was usually no link to the broader regional or sub-regional economy.

The Lowry model (Lowry, 1964) was an attempt to integrate different urban sub-models within a more comprehensive model, where the extra-urban area was treated exogenously. The Lowry model is still, however, partial, focussing as it does on interaction and land use, ignoring the interrelationships between industries and the effects of externalities. The variable which drives the Lowry model is (exogenously given) basic employment. A number of demographic models, some of which include the property market, also represent an attempt to treat the sub-regional economy in a more comprehensive manner, again treating the extra-urban areas as exogenous.

There are substantial differences between the two approaches. The input–output approach is based upon monetary values and is centred upon the commodity market, whilst the urban land use models are usually based on factor markets: the labour market (Hyclak and Johnes, 1992; Broersma and van Dijk, 2002) and the property market (Paez et al., 2001), where the units of measurement are customarily employment in physical terms and area. In land use modelling, supply and demand in the commodity market, at least for basic activities, is treated exogenously, whereas in the regional input–output modelling approach, region-internal (typically urban) activity is either not included at all, or is treated in a summary manner. In the input–output approach the prime categories of the analysis are industries, whilst in the land-use approach industries are largely absent and categories representing institutions (for example, households) are often more disaggregated.

A number of different modelling developments have attempted to integrate and reconcile these two different approaches.

Demo-economic modelling expands the interregional input–output model with demographic and labour market components (Batey and Madden, 1981; Madden and Batey, 1983; Madden and Trigg, 1990; Oosterhaven and Folmer, 1985; Stelder and Oosterhaven, 1995). In this approach there is an explicit distinction between place of production and place of residence, so that a degree of integration between local and regional models is achieved. However, these types of models do not operate with a distinction between place of residence and place of demand, nor do they use different price concepts.

Interregional SAM models expand the interregional input–output model with a labour market and an institutional component (Round, 1995; Kilkenny and Rose, 1995; Hewings and Madden, 1995a,b; Madsen and Jensen-Butler, 2002b). However, though local economic interaction, such as commuting or shopping, is an element of the logical structure of the models, this interaction is not usually modelled in real terms. This in turn means that the concepts of place of production, place of residence and place of demand are not explicitly defined in relation to the different actors in the SAM. The same is true for different price concepts in this modelling approach. Even though there is a distinction between fixed and current prices in the interregional SAM models, permitting the calculation of price indices, in these models usually only the real Keynesian circle is in the model, the dual cost-price model not being incorporated. Also, the distinction between basic prices and market prices is often not used in a precise manner.

Interregional computable general equilibrium (CGE) models address this last issue, introducing explicitly the interaction between real economic activity (produc-

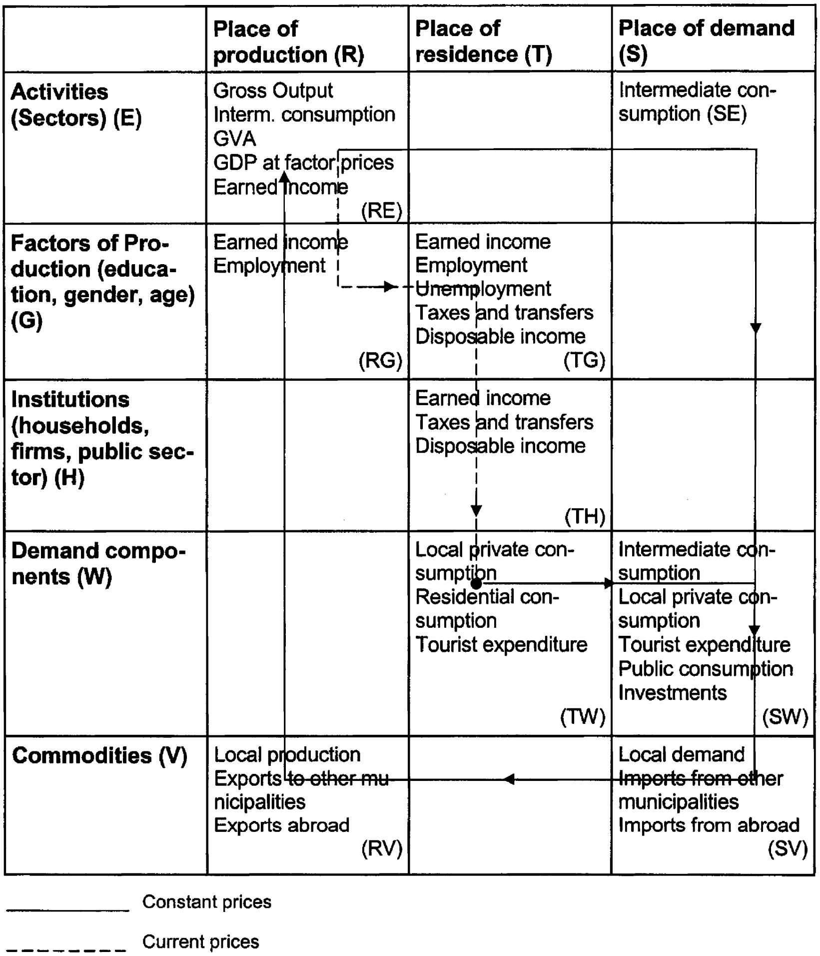

Fig. 1. A simplified version of LINE: the real circle.

tion and demand) and costs and prices in a spatial context (Van den Bergh et al., 1996; Bröcker, 1995, 1998, 2002; Harrigan et al., 1991; McGregor et al., 1998; Haddad et al., 2002). CGE models are also used to assess efficiency and distributional aspects of development trends, and policy measures. Normally, CGE models deal with the regional level (place of production) and with the market for goods and services, whilst distributional questions within a region are not usually dealt with. Also, local economic processes transforming demand from place of demand to place of production and through place of residence back to place of demand is usually absent. Likewise, the transformation of prices from place of production to place of demand, to place of residence and back to place of production is also usually absent. A strength of these types of model is the fact that they incorporate substitution and income effects on both consumption and production, even though solutions to the models are often mathematically complex.

The modelling approach presented here involves the development of the LINE model, which has been applied in a number of studies to Danish regions. It is based upon an extended interregional SAM, which means that the model is fundamentally monetary. The smallest areal unit employed in the model is the Danish municipality (the kommune, having on average approx. 20 000 inhabitants), which makes LINE a local or sub-regional model. This is the lowest level of the Danish administrative hierarchy, there being 275 kommunes. The model can also run at the regional level, corresponding to the second tier of the administrative hierarchy, the county, of which there are 16. At the top level there is the state. An intermediate areal division, also used in LINE is the labour market district, these being homogenous labour market areas, of which there are 45, defined by Andersen (2002a). The basic structure of LINE involves the SAM actors (activities, factors, institutions, needs and commodities) and a geographical dimension with (i) place of production, (ii) place of residence and (iii) place of demand, making the model interregional. It incorporates both a real Keynesian circle and a cost-price circle, which interact. LINE thus integrates the interregional input–output and the more local land use modelling approaches. In the present version links between the real circle and the cost-price circle are established, though the mathematical treatment remains relatively straightforward and linear. In principle, distributional questions within a region are addressed by the model, although substitution effects on both commodity and factor markets have not yet been included.

In the following, the model is first presented graphically in Section 3, where references to the full mathematical derivation are provided. In Section 4 different versions of LINE are described; each representing different reduced models and different types of aggregation in relation to the full model. In Section 5, a concrete example of LINE is presented, a model designed to examine the effects of eliminating tolls for passage of the Great Belt fixed link in Denmark and in Section 6, results of the use of this model in relation to the Great Belt problem are presented. In Section 7, model development strategies are examined.

3. LINE: the full model, a graphical presentation

Here, a brief graphical presentation of LINE is made. The full model and its equations are described in detail in Madsen et al. (2001a). The data used in the model, together with the interregional SAM, are described in Madsen and Jensen-Butler (2002b) and Madsen et al. (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. Fig. 1 shows the general model structure, based upon the real circuit employed in LINE.

The horizontal dimension is spatial: place of work (denoted as R), place of residence (T) and place of demand (S). Production activity is related to place of work. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of demand. The vertical dimension is more detailed and follows with its five-fold division, the general structure of a SAM model. Production is related to activities; factor incomes are related to (i) activities by sector, (ii) factors of production with labour by sex, age and education, (iii) institutions: households, (iv) demand for commodities is related to wants (aggregates of commodities or components of final demand and intermediate consumption) and (v) commodities, irrespective of use.

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in Fig. 1. Starting in cell RE in the upper left corner, production generates factor incomes in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors (RE) to sex, age and educational groups (RG). Factor income is then transformed from place of production (RG) to place of residence (TG) through a commuting model. Employment follows the same path from sectors (RE) to sex, age and educational groups (RG) and further from place of production (RG) to place of residence (TG). Employment and unemployment are determined at place of residence (TG). Employment refers both to place of production and to place of residence, whereas unemployment and the labour force, by definition, only can be related to place of residence. This also explains the relationship of earned income to both place of production and place of residence, whereas other income, transfer incomes and personal taxes, by definition only can be related to place of residence.

Disposable income is calculated in a sub-model where taxes are deducted and transfer and other incomes are added. Disposable income is distributed from factors (TG) to households (TH). This is the basis for determination of private consumption by type of household in market prices, by place of residence (TW). Private consumption is divided into tourism (domestic and international) and local private consumption. Private consumption is assigned to place of demand (SW) using a shopping model for local private consumption and a travel model for domestic tourism. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities (SV) in basic prices through a use matrix, including information on the commodity composition of demand and commodity tax rates and trade margin shares. In this transformation from market prices to basic prices (from SW to SV) commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production. Through a trade model exports to other regions and production for the region itself are determined (from SV to RV). Adding export abroad, gross output by commodity is determined (RV). Through a reverse make matrix the cycle returns to production by sector (from RV to RE).

The stylised version of the model with the real circle illustrated, as well as the price concepts used, is shown in Fig. 1, where the price level of real circle variables (constant/current) is shown.

Using again the stylised version of the model shown in Fig. 1, the anticlockwise cost/price circuit shown in Fig. 2 corresponds to the dual problem. In the cost-price circle, production and demand are calculated in current prices, which in turn are transformed into relevant price indices. In cell RE sector basic prices (current

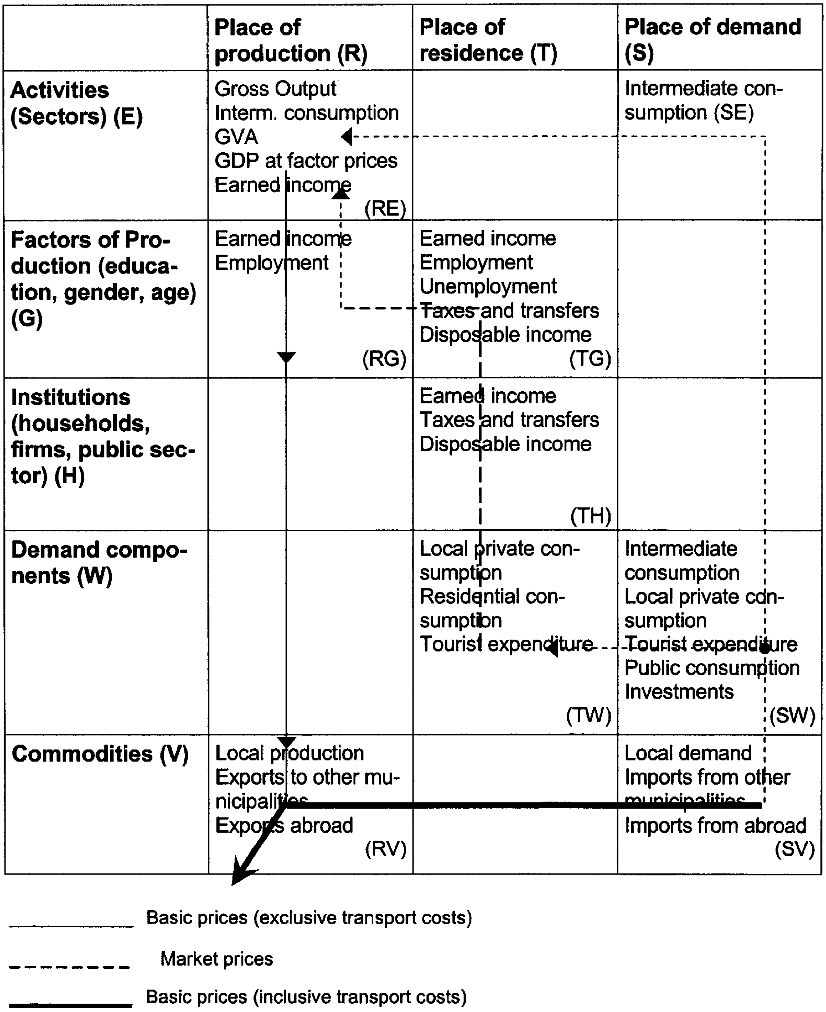

Fig. 2. A simplified version of LINE: the cost-price circle.

prices) are determined by costs (intermediate consumption, value added and indirect taxes, net in relation to production). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (from RE to RV). These are then transformed from place of production to place of demand (RV to SV) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes (from SV to SW). This transformation takes place using a reverse use matrix. Finally, private consumption is transformed from place of demand to place of residence in market prices (from SW to TW). Fig. 3 shows the structure of LINE in more detail.

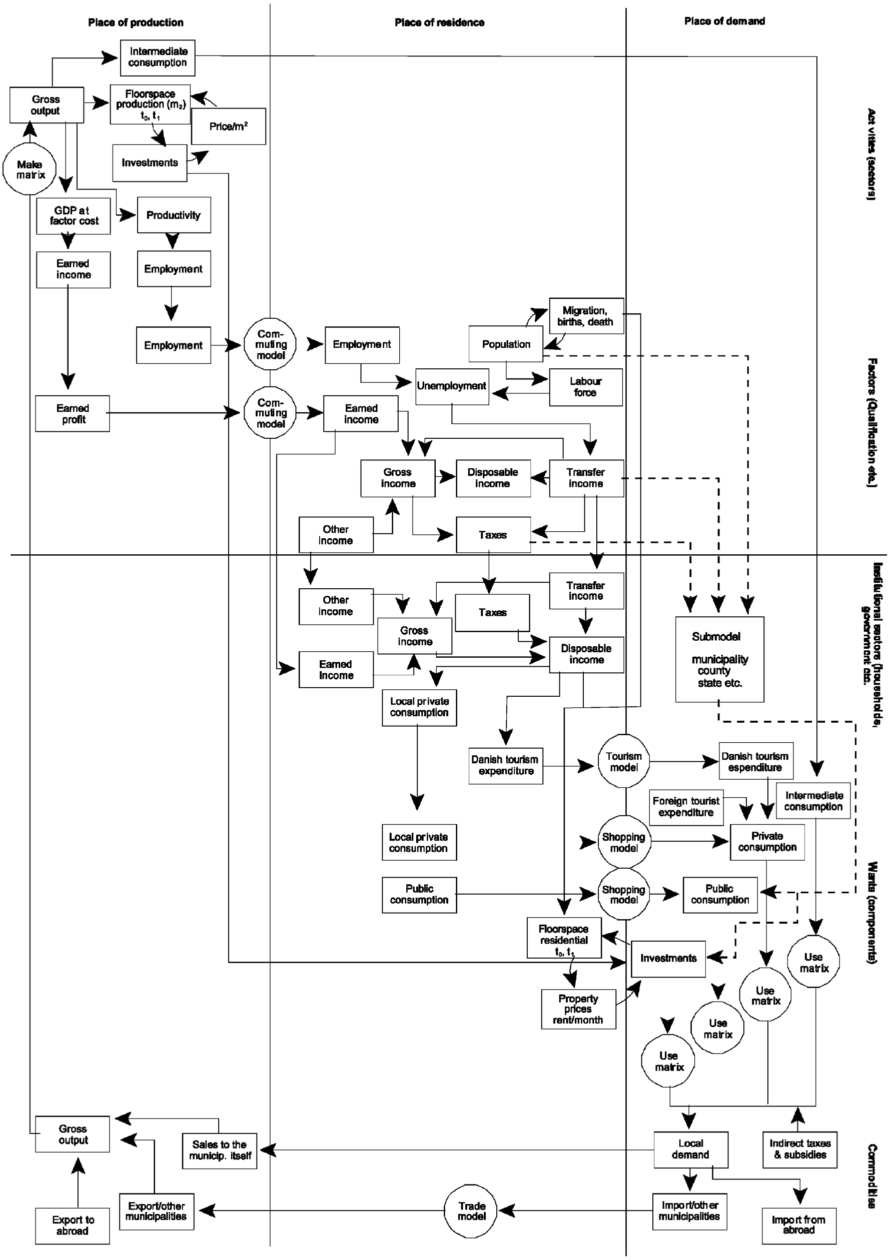

Fig. 3. LINE, the full model.

3.1. The dimensions of LINE

In the standard version of LINE (though not used here in the Great Belt study) the dimensions of the axes are normally the following:

Sectors: 12 sectors aggregated from the 133 sectors used in the national accounts.

Factors: 7 age, 2 sex and 5 education groups.

Households: 4 types, based upon household composition

Needs: For private consumption and governmental individual consumption, 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.

Commodities: 20 commodities, aggregated from 131 commodities used in the national accounts.

Regions: 277 municipalities, including one state-owned island and one unit for extra-regional activities, this being the lowest level of spatial disaggregation. Regions are defined either as place of production, place of residence or as place of demand. It is possible to aggregate the (277) municipalities into any regional unit. Standard regions are the (17) counties (including a region for extra-regional activities) and (46) labour market districts, both including one unit for extra-regional activities.

4. Model flexibility

LINE has been designed with a high degree of flexibility so that different elements of the model can be either used in different types of analysis, or they can be removed by aggregation. The remaining dimensions and categories can be aggregated in different ways. Also, different sub-models (such as the municipality budget model) can either be included or excluded.

As an example of the choices to be made with respect to aggregation, factors of production, in particular labour, could be disaggregated by age, sex and educational group at one extreme, or at the other, they could be aggregated into one group. The treatment of commuting provides one example. Many commuting models (for example, Artis et al., 2000; Casado-Diaz, 2000; Green et al., 1986) incorporate individual features of workers and households in their explanation of commuting patterns. Disaggregation along these lines could be incorporated into the specific version of LINE if regional labour markets were the focus of interest and if the results of the analysis indicated that such categories are found to add explanatory power. In this concrete study, presented below, the choice has been made not to include a subdivision of factors and households, as this is not a labour market study. Thus, it is assumed that changes in transport costs, other things being equal, have the same effect on each sub-group. The literature suggests that this may not be the case (Simpson, 1992) and there may, in fact, be distributional effects arising from changes in transport costs, though initially, in the case of the Great Belt tolls, these are not believed to be great. One of the aims of the present paper is to illustrate an application of the model rather than undertake a specific and detailed regional economic analysis. It must also be remembered that a highly disaggregated version of the model places substantial demands on computational capacity.

In addition, inside each module, the number of industries used in any concrete analysis can be varied, the number chosen and their composition being derived from aggregation of the 133 industries in the SAM. The same flexibility in aggregation applies to the other axes of the model, regions, factors, institutions, components of needs and commodities.

By way of illustration, Table 1 shows Danish studies where the model has been used and the configuration employed, constituting a specific version of LINE.

The rows in Table 1 show studies where LINE has been used. A detailed description of each, including the model configuration used, can be found in the documentation noted below the table. A detailed examination of the Great Belt tolls study follows.

The columns show which axes have been used (×) and which have been removed (blank) in each study. Removal means that the axis has been aggregated into one category or index, all calculations being performed for this category. Regions and SAM components have been described in Section 3. Real circle I means that only a part of the circle has been executed: from primary income and employment at place of production (RE) to disposable income for households by place of residence in current prices (TH). Real circle II goes from real disposable income for households by place of residence (TH) to GDP in current prices at place of production (RE). An × in the cost-price circle column indicates that the cost price circle has been included. An × in the link column indicates that the two circles have been linked, an issue, which is developed in Section 6. Top-down indicates that model calculations have been undertaken under the constraint of alternative national forecasts, using different national macroeconomic models (Dam, 1995, Frandsen et al., 1995). Bottom-up indicates an unconstrained model calculation using LINE.

5. Application of LINE: model structure and configuration

To illustrate the use of the model, its application to the case of the Danish Great Belt link is demonstrated. The Great Belt fixed link is a central element in the Danish motorway system. The study addresses the problem of identification of the regional economic consequences of removal of the substantial tolls, which are today charged for passage.

In this section, the issues are briefly presented, followed by a presentation of the model configuration and equations. In Section 6 the results of the case study are examined.

The Great Belt link toll policy has been chosen as a case for a number of reasons. First, it illustrates the general equilibrium application of LINE. Second, it provides an example where the three geographical components of LINE (place of production, place of demand and place of residence) are all important, as the changes in transport costs affect in different ways different types of activity and location. Third, the effects of the changes in transport costs are different for the different SAM

Table 1
Examples of studies based upon LINE

Study:	Regions				SAM components							Model circle				Model hierarchy	
	Regional level	Place of production	Place of residence	Place of demand	Activities	Factors			Institutions	Needs	Commodities	Real circle I	Real circle II	Cost/price circle	Link between circles	Top down	Bottom up
						Age	Sex	Educ									
Rural development/scenarios:																	
Rural area development[a]	Mun	X	X		X				X			X					X
Agriculture and environmental policy[b]	Mun	X	X	X	X				X	X	X	X	X			X	
Industry[c]	Mun	X	X	X	X				X	X	X	X	X				X
Tourism[d]	Cty	X	X	X	X	X	X	X	X	X	X	X	X				X
Residential/ settlement[e]	Mun	X	X	X	X	X	X	X	X	X	X	X	X				X
Welfare state[f]	Mun	X	X		X				X			X				X	
Other analyses:																	
Gr Copenhagen Development[g]	Mun	X	X		X				X			X					X
Road pricing[h]	Cty	X	X	X	X				X	X	X	X	X	X			X
GrBelt tolls[i]	Cty	X	X	X	X				X	X	X	X	X	X	X		X
Income growth decomposition[j]	LabM	X	X	X	X	X	X	X	X	X	X	X	X				X
Labour market[k]	Cty	X	X	X	X	X	X	X	X	X	X	X	X			X	
New economy Gr.Copenhagen[l]	Cty	X	X	X	X	X				X	X	X	X				X

Mun: kommune level; Cty: County level; LabM: Labour market district level.
[a] Jensen-Butler et al. (2002);
[b] Hasler et al. (2002);
[c] Andersen and Christoffersen (2002);
[d] Zhang (2001);
[e] Andersen (2002b);
[f] Dam et al. (1997);
[g] Sørensen (1998);
[h] Madsen and Jensen-Butler (2001);
[i] Madsen et al. (2002);
[j] Madsen and Jensen-Butler (2002a);
[k] Holm et al. (2002);
[l] Telle and Hanghoj (2002).

Fig. 4. Danish regions (counties and two municipalities with county status, Copenhagen M and Frederiksberg M). Three fixed links: (A) Oresund to Malmo, Sweden, (B) Great Belt, (C) Femer Belt to Germany. Four ferry routes: (D) Spodsbjerg–Taars, (E) Odden–Aarhus (Mols Line), (F) Odden–Ebeltoft (Mols Line), (G) Frederikshavn–Gothenburg (Sweden). Other very local and international ferry routes are not shown.

components. Finally, public interest in this issue is considerable, which in turn generates policymakers' interest.

5.1. The Great Belt link and toll policy

The location of Danish Great Belt fixed link, is shown in Fig. 4, which also shows the Danish regions used in the model (see also Jensen-Butler and Madsen, 1996). The link is interregional and is centrally placed in the geography of Denmark. A change in toll charge policy will have more marked effects on commodity trade (including trade in services) and tourism, whilst the effects on shopping and commuting will be more limited. The fixed link, which includes both road and rail, is 16-km long and at present tolls are charged for passage of vehicles. These tolls are substantial, being of the order of €30 (approximately the equivalent amount in $US) for a one-way journey for a car, and five times this amount for a lorry. For rail passengers, tolls are not charged, though the railway company pays a fixed annual amount to the (state) company owning the fixed link, which affects ticket prices. There is at present a proposal to reduce tolls to zero.

There are two ways of crossing between East and West Denmark: the fixed Great Belt link and ferries, as shown in Fig. 4.

5.2. Model configuration and aggregation for the Great Belt toll study

The precise form of the model used is determined by the requirements of the study, which in turn determines both model configuration and level of aggregation.

5.2.1. Configuration

As can be seen in Table 1 the version of LINE for this study has the following configuration:

1. Both the real and cost/price circles are included because the aim of the study is to estimate changes in commodity prices after a change in transport costs and to estimate the consequences for demand of changes in disposable income and foreign imports and exports, due to the effects of changes in tolls.
2. The three types of location, place of production, place of residence and place of demand have been used to calculate the changes in transport costs through trade, shopping, tourism and commuting.
3. Industries and commodities are included as the importance of transport varies markedly between industries and commodities.
4. Production factors as a single undifferentiated component.
5. Households as a single undifferentiated component.
6. Components of needs are related to transport effort in relation to shopping and tourism.

5.2.2. Aggregation

The version of LINE used in this study has 17 regions, corresponding to the Danish counties, including the municipalities of Copenhagen and Frederiksberg, which have county status as well as a unit for extra-regional activities. Fig. 4 shows the regions used. 23 sectors and 27 commodities are used, including the transport commodity and sector, covering all types of transport. 13 components of private consumption, 8 components of public consumption and 10 investment components are employed. Factors are divided into wages and profits, though in this case age, sex and educational level are not used, as the distributional effects here are considered to be of limited importance. Institutions include households and the governmental sector. Households have not been subdivided into types as again, the distributional effects are, as noted above, assumed to be limited. Of course, the optimal configuration in this case would be inclusion of all axes in full detail. For

Table 2
Make matrix by regions

		Commodities	Total supply
Local output	By sector	$\mathbf{V}^{R,L}$	$\mathbf{V}_{E}^{R,L}$
	Total	$\mathbf{V}_{V}^{R,L}$	$\mathbf{V}_{V,E}^{R,L}$
Imports from abroad	By country	$\mathbf{V}^{R,F}$	$\mathbf{V}_{W}^{R,F}$
	Total	$\mathbf{V}_{V}^{R,F}$	$\mathbf{V}_{V,W}^{R,F}$
Total supply		$\mathbf{V}_{V}^{R}$	$\mathbf{V}^{R}$

example, changes in transport costs in the Great Belt link case might be different for factors and household sub-groups, which in turn might lead to behavioural reactions in the labour market, in tourism destination choice, etc. However, if the focus is the general regional economic consequences, and not the distributional consequences for different types of person and household, a less detailed model can be used.

5.3. Defining the variables

Central elements in the model are the Make and Use matrices and the trade matrices. Tables 2–4 show the structure and notation for the Make, Use, and Commodity Balance and Trade matrices used in the model. **V** is a Make matrix, **U** a Use matrix and **Z** an interregional trade matrix. The superscripts used are as follows: *R* denotes region of supply; *S* denotes region of demand; *L* denotes local (regional) origin of supply and demand; *O* denotes an other-region origin of supply and demand; *F* denotes foreign origin of supply and demand; *D* denotes domestic (all domestic regions). The subscripts used are as follows: *V* denotes commodity; *E* denotes sector; *W* denotes a component of final demand (or country group); *IC* denotes intermediate consumption; *CP* denotes private consumption; *CO* denotes public consumption; *I* denotes investment. In the equations which follow, the Use matrix in coefficient form is defined as **B**, the Make matrix in coefficient form is defined as **D** and the trade matrix is **T**. This is the same notation as used in Madsen and Jensen-Butler (1999). All variables are measured in fixed prices except for the case where there is a superscript *C*, denoting current prices. The price index for a given variable in matrix or vector form is denoted by a prefix *P*.

In the following presentation of the model, the dimensions have been further aggregated in order to present the fundamental structure of LINE, rather than showing extensive detail. No distinction is made between wants and commodities and VAT and commodity taxes are not included.

5.4. Conventional production—fixed prices[1]

In the real circle, first, gross value added (GVA) by place of production is determined by gross output (in Fig. 1, cell RE):

[1] In this section, almost all variables are in fixed prices. In the extended LINE disposable income, etc. are modelled in current prices.

Table 3
Use matrix by region

	Intermediate consumption		Private consumption		Public consumption		Investment		Local demand	Foreign exports		Total demand
Commodities	$\mathbf{U}_{IC}^{S,L}$	$\mathbf{U}_{V,IC}^{S,L}$	$\mathbf{U}_{CP}^{S,L}$	$\mathbf{U}_{V,CP}^{S,L}$	$\mathbf{U}_{CO}^{S,L}$	$\mathbf{U}_{V,CO}^{S,L}$	$\mathbf{U}_{1}^{S,L}$	$\mathbf{U}_{V,J}^{S,L}$	$\mathbf{U}_{V}^{S,L}$	$\mathbf{U}^{SF}$	$\mathbf{U}_{V}^{S,F}$	U_{V}^{S}
Total demand	$\mathbf{U}_{E,IC}^{S,L}$	$\mathbf{U}_{V,E,IC}^{S,L}$	$\mathbf{U}_{W,CP}^{S,L}$	$\mathbf{U}_{V,W,CP}^{S,L}$	$\mathbf{U}_{W,CO}^{S,L}$	$\mathbf{U}_{V,W,CO}^{S,L}$	$\mathbf{U}_{W,1}^{S,L}$	$\mathbf{U}_{V,W,1}^{S,L}$	$\mathbf{U}^{SL}$	$\mathbf{U}_{W}^{S,F}$	$\mathbf{U}_{V,W}^{S,F}$	U^{S}

Table 4
Commodity balance and trade

	The region itself	Other regions	Production for the domestic market	Export Abroad	Total production
The region itself	$\left[\mathbf{Z}_V^{R,L}(=\mathbf{Z}_V^{S,L})\right.$	$\left.\mathbf{Z}_V^{R,O}\right]$	$\mathbf{Z}_V^{R,D}$	$\mathbf{Z}_V^{R,F}(=\mathbf{U}_V^{S,F})$	$\mathbf{Z}_V^{R}(=\mathbf{V}_V^{R,L})$
Other regions	$\left[\mathbf{Z}_V^{S,O}\right.$	$\left.\mathbf{Z}_V^{R,S,O}\right]$			
Domestic demand	$\mathbf{Z}_V^{S,D}$				
Foreign imports	$\mathbf{Z}_V^{S,F}(=\mathbf{V}_V^{R,F})$				
Total demand	$\mathbf{Z}_V^{S}(=\mathbf{U}_V^{S,L})$				

[ ]: These four matrices constitute the gross intra and interregional trade matrix $\mathbf{Z}_V^D$.

$$H^R = i^E(X^R - ((i^V)' \ B_{IC}^{S,L}\hat{X}^R)), \tag{1}$$

where:

H^R: GVA by place of production R

X^R: Gross output, by industry, by place of production R

$B_{IC}^{S,L}$: Intermediate consumption (IC), as a part of local demand (L), as share of gross output, by industry, at place of production S[2]

i^V, i^E: Unity vectors for commodities and industries, respectively

^: Denotes a diagonalised version of previously defined variable, in this case X^R

′: Denotes transposition of a matrix or vector

Gross value added by place of production is transformed into disposable income at place of residence by subtracting commuting costs from income (from cell RG to TG):

$$\begin{aligned} H^T &= ((i^R)' \ \ (1 - B^{R,T}_{V=\text{tr, commuting, } CP}) \quad \# J^{R,T}\hat{H}^R)' \\ &= ((i^R)' \ \ (1 - B^{R,T}_{V=\text{tr, commuting, } CP}) \quad \# H^{R,T})', \end{aligned} \tag{2}$$

where:

H^T: Disposable income (income net of transport expenditure) by place of residence T

$B^{R,T}_{V=\text{tr, commuting, } CP}$: Demand for transport commodity for commuting (as a part of private consumption) as share of factor income by place of residence T and place of production (work) R

$J^{R,T}$: Commuting coefficient matrix by place of residence T and place of production (work) R

$H^{R,T}$: Gross value added by place of production R and place of residence T

[2] Which is by definition equal to place of production R.

#: Cell-by-cell multiplication
1: Matrix containing values of unity

The input to the step ($B^{R,T}_{V=tr,commuting,CP}$) is data for commuting cost in value terms. In the following other elements of transport costs are used.

Private consumption by place of residence is calculated as follows (cell TW):[3]

$$U^{T,L}_{V,CP} = B^{T,L}_{V,CP}\hat{H}^{T}, \tag{3}$$

where:

$U^{T,L}_{V,CP}$: Private consumption, *CP*, by commodity *V*, as part of local demand *L*, by place of residence *T*.

$B^{T,L}_{V,CP}$: Private consumption *CP*, by commodity *V*, as a part of local demand, as a share of disposable income by place of residence *T*

Private consumption by place of demand is calculated (from cell TW to SW):

$$\begin{aligned} U^{S,L}_{V,CP} &= ((i^{T})' \;\; (1 - B^{T,S}_{V=\text{tr, shopping, } CP}) \;\; \# K^{T,S}_{V} \hat{U}^{T,L}_{V,CP})' \\ &= ((i^{T})' \;\; (1 - B^{T,S}_{V=\text{tr, shopping, } CP}) \;\; \# U^{T,S,L}_{V,CP})', \end{aligned} \tag{4}$$

where:

$U^{S,L}_{V,CP}$: Private consumption, *CP*, by commodity *V*, as part of local demand *L*, by place of demand *S*

$B^{T,S}_{V=\text{tr,commuting},CP}$: Demand for transport commodity (as a part of private consumption), for shopping as share of private consumption by place of residence *T* and place of demand *S*

$K^{T,S}_{V}$: Shopping coefficient matrix by place of residence *T* and place of demand *S*

$U^{T,S,L}_{V,CP}$: Private consumption, *CP*, by commodity *V*, by place of residence *T* and place of demand *S*

Intermediate consumption is determined by gross output (from cell RE to SV):

$$U^{S,L}_{V,IC} = (i^{E}) \;\; B^{S,L}_{IC}\hat{X}^{R}, \tag{5}$$

where:

$U^{S,L}_{V,IC}$: Intermediate consumption, *IC*, by commodity *V*, as part of local demand *L*, by place of demand *S*

$B^{S,L}_{IC}$: Intermediate consumption, *IC*, by commodity and by sector, as a share of gross output, by place of demand *S*

[3] In the theoretical model this refers to TV rather than TW. In this more simple presentation commodities (*V*) have been summed to give wants (*W*).

Total local demand is given by (cell SV):

$$U_V^{S,L} = U_{V,IC}^{S,L} + U_{V,CP}^{S,L} + U_{V,CO}^{S,L} + U_{V,I}^{S,L}, \tag{6}$$

where:

$U_V^{S,L}$: Total local demand L, by commodity V, by place of demand S. The subscripts IC, CP, CO and I represent the components of local demand: intermediate consumption, private consumption, public consumption and investment, respectively.

Public consumption and investment are given exogenously.

Local demand, which is supplied domestically, is determined by subtracting foreign imports (cell SV):

$$Z_V^{S,D} = U_V^{S,L} - Z_V^{S,F}, \tag{7}$$

where:

$$Z_V^{S,F} = T_V^{S,F} \# U_V^{S,L}, \tag{8}$$

where:

$Z_V^{S,D}$: Domestically supplied local demand D by place of demand S and commodity V

$Z_V^{S,F}$: Foreign imports F by place of demand S and commodity V

$T_V^{S,F}$: Foreign imports F as share of local demand by place of residence S and commodity V

Domestic production is determined by a trade model (from cell SV to RV):

$$Z_V^{R,D} = ((1 - B_{V=tr,\text{int.trade},IC}^{R,S}) \# T_V^D \hat{Z}_V^{S,D})\ i^S = ((1 - B_{V=tr,\text{int.trade},IC}^{R,S}) \# Z_V^{R,S,D})\ i^S, \tag{9}$$

where:

$Z_V^{R,D}$: Gross output for domestic demand D by place of production R and commodity V

$B_{V=\text{tr,int.trade},IC}^{R,S}$: Demand for the transport commodity as an intermediate commodity as share of trade by place of demand S and place of production R

T_V^D: Domestic (D) trade between place of production and place of demand as share of local demand for domestic production by commodity V

$Z_V^{R,S,D}$: Domestic trade between place of production R and place of demand S and by commodity V

Foreign exports are determined by subtracting transport costs (cell RV):

$$Z_V^{R,F} = ((1 - B_{V=\text{tr,foreign.trade},IC}^{R,F}) \;\#T_V^{R,F}\hat{Z}_{V,MP}^{R,F})i^F$$
$$= ((1 - B_{V=\text{tr,foreign.trade},IC}^{R,F}) \;\#Z_{V,MP}^{R,F})i^F, \tag{10}$$

where:

$Z_V^{R,F}$: Foreign exports F by place of production R by commodity V

$B_{V=\text{tr,foreign.trade},IC}^{R,F}$: Demand for the transport commodity for transport as an intermediate commodity as share of foreign exports (F) by country group (as B is municipality × group of countries) and by place of production R

$T_V^{R,F}$: Foreign exports (F) by country group as share of total foreign exports, by commodity V and by place of production R

$Z_{V,MP}^{R,F}$: Foreign exports F by place of production R by commodity V, in market prices MP

By adding foreign exports, local production can be calculated (cell RV):

$$V_V^{R,L} = Z_V^R = Z_V^{R,D} + Z_V^{R,F}, \tag{11}$$

where:

$V_V^{R,L}, Z_V^R$: Local gross output by place of production R, by commodity.

Transforming gross output by commodity to gross output by sector closes the real circle (RE):

$$X^R = (D^{R,L} \;\hat{Z}_V^{R,L})i^V, \tag{12}$$

where:

$D^{R,L}$: The make matrix.

5.5. Production in the transport sector—fixed prices

As can be seen in this model description, transport costs enter into the model in different ways. First, for households, transport costs appear in relation to commuting as a deduction from household income and purchases of goods include transport costs involved with transporting the goods to place of residence. Second, for firms, wage costs are gross and include payment of commuting costs. It is assumed that the seller pays transport costs (fob). The firms' revenues from sale of commodities, therefore, exclude transport costs.

The approach used here is the inverse of the well-known *iceberg concept* (Samuelson, 1954) implying the inverse of the idea that a part of the commodities disappear on the way to the market. The cost approach used here corresponds to an increase in the price of the product under transport to the market.

Demand for transport can be determined by adding up:

$$U^{R,T}_{V=\text{tr,commuting},CP} = B^{R,T}_{V=\text{tr,commuting}} \ \# H^{R,T} \tag{13a}$$

$$U^{T,S}_{V=\text{tr,shopping},CP} = B^{T,S}_{V=\text{tr,shopping}} \ \# U^{T,S}_{V,CP} \tag{13b}$$

$$U^{R,S}_{V=\text{tr,ir.trade},IC} = B^{R,S}_{V=\text{tr,ir.trade}} \ \# Z^{R,S}_{V} \tag{13c}$$

$$U^{R,F}_{V=\text{tr,for.trade},IC} = B^{R,F}_{V=\text{tr,for.trade}} \ \# U^{R,F}_{V}, \tag{13d}$$

where:
$\boldsymbol{U}^{O,D}_{V=\text{tr,xxx.yyy}}$: Demand for transport commodity for economic transactions between regions O and D for interaction type xxx and demand category yyy. For interaction type commuting, xxx = commuting and demand category private consumption = CP, $O=R$ and $D=T$.

Assuming that demand for transport for commuting and shopping (private consumption) are related to place of residence T, the following holds:

$$U^{T,L}_{V=tr,CP} = ((i^R)' U^{R,T}_{V=\text{tr,commuting},CP})' + (U^{T,S}_{V=\text{tr,shopping},CP}) i^S \tag{14a}$$

For inter-regional trade and foreign trade, it is assumed that demand for transport (intermediate consumption) is related to place of production:

$$U^{R,L}_{V=\text{tr},IC} = (U^{R,S}_{V=\text{tr,ir.trade},IC}) i^S + (U^{R,F}_{V=\text{tr,foreign.trade},IC}) i^F \tag{14b}$$

From this step the transport commodities are treated in the same way as all other commodities: In the first step, private consumption of transport commodities is transformed into place of demand (shopping) and intermediate consumption of the transport commodities is added. In the second step, total demand, trade and production of transport commodities are determined like demand and production for all other commodities. In the third step, gross output in the transport sector and other transport commodity producing sectors (e.g. the sector-internal production of transport commodities) is determined.

5.6. Conventional production—current prices[4]

In the simple version, the real circuit is modelled almost exclusively in fixed prices. In the cost-price circle, variables are transformed into current prices. Starting from the determination of labour supply as a function of prices of commodities, wage rates and allocation of time, as described above, gross value added in current prices is determined.

[4] In this section most variables are in current prices. Current price variables are indicated with an upper C.

Economic activities in current prices are modelled using a mark-up principle. Gross output in current prices is determined as follows (in Fig. 2, cell RE):

$$X^{R,C} = (PUK_{IC}^{S,L} \ \# U_{IC}^{S,L} P\hat{U}_{V,\text{demand.cat}=IC}^{S,L}) \ i^{V} + H^{R,C}, \tag{15}$$

where:
$PUK_{IC}^{S,L}$: Price correction matrix (PK) for intermediate consumption (U), by commodity and by sector and by place of demand S
$P\hat{U}_{V,\text{demand.cat}=IC}^{S,L}$: Commodity prices for intermediate consumption IC, by commodity V and place of demand S
$U_{IC}^{S,L}$: Intermediate consumption by commodity and sector at place of demand S

The superscript C denotes current prices.
An output price index can now be determined implicitly:

$$PX^{R} = X^{R,C}/X^{R}, \tag{16}$$

where:
PX^{R}: Price index by sector and by place of production R.

Gross output by sector in current prices can be transformed into gross output by commodity using a sector price index (from RE to RV):

$$V^{R,L,C} = PVK^{R,L} \ \# V^{R,L} P\hat{X}^{R} \tag{17a}$$

$$V_{V}^{R,L,C} = ((i^{E})' V^{R,L,C})', \tag{17b}$$

where:
$PVK^{R,L}$: Price correction matrix by commodity and by sector and by place of production R.

An output commodity price index can now be determined implicitly:

$$PV_{V}^{R,L} = V_{V}^{R,L,C}/V_{V}^{R,L}, \tag{18}$$

where:
$PV_{V}^{R,L}$: Prices by commodity V, by place of production R.

In a similar way, both sector prices and commodity prices for all sectors and commodities, including the transport sector and commodity, can be determined.
In the next step foreign exports (RV) in current prices are determined:

$$Z_V^{R,DF,C} = PZK_V^{R,DF} \;\#Z_V^{R,DF} P\hat{V}_V^{R,L}, \tag{19}$$

where:

$PZK_V^{R,DF}$: Price correction matrix for domestic and foreign sales by commodity V and by place of production R

$Z_V^{R,DF}$: Gross output divided between foreign and domestic demand by commodity V and place of production R

Basic prices for output produced both for foreign and domestic markets can now be determined:

$$PZ_V^{R,DF} = Z_V^{R,DF,C} / Z_V^{R,DF}, \tag{20}$$

where:

$PZ_V^{R,DF}$: Implicit basic price index for foreign (F) and domestic (D) sales by commodity V and place of production R. Now foreign market prices in current prices can be determined by adding transport cost in current prices:

$$Z_V^{R,F,C} = PZK^{R,F} \;\#Z^{R,F} PZ_V^{R,DF=F} + U_{V=\mathrm{tr,for.export},IC}^{R,F,C} \tag{21a}$$

A country-specific implicit price index for foreign market prices can be derived:

$$PZ_V^{R,F} = Z_V^{R,F,C} / Z_V^{R,F}, \tag{21b}$$

where:

$PZ_V^{R,F}$: Implicit market price index for foreign sales by country and by commodity V and pl ace of production R.

Interregional trade in current market prices can be calculated as follows (from RV to SV):

$$Z_V^{D,C} = PZK_V^{D} \;\#Z_V^{D} (PZ)_V^{R,DF=D} + U_{V=\mathrm{tr,ireg.trade},IC}^{R,S,C} \tag{22a}$$

$$Z_V^{S,D,C} = ((i^R)' Z_V^{D,C})' \tag{22b}$$

$$PZ_V^{S,D} = Z_V^{S,D,C} / Z_V^{D,C} \tag{22c}$$

By adding imports from abroad, local consumption in market prices can be determined (SV):

$$U_V^{S,L,C} = Z_V^{S,D,C} + PZK_V^{S,F} \;\#Z_V^{S,F} (P\hat{Z})_V^{S,F} \tag{23a}$$

An implicit index for local market prices by commodity can now be derived:

$$PU_V^{S,L} = U_V^{S,L,C} / U_V^{S,L} \tag{23b}$$

Local demand for commodities can be divided into categories of demand. For each category the market price by commodity is calculated in the following manner:

$$U_{V,\text{demand.cat}}^{S,L,C} = PUK_{\text{demand.cat}}^{S,L} \;\#U_{V,\text{demand.cat}}^{S,L} (P\hat{U})_V^{S,L} \tag{24a}$$

$$PU_{V,\text{demand.cat}}^{S,L} = U_{V,\text{demand.cat}}^{S,L,C} / U_{V,\text{demand.cat}}^{S,L} \tag{24b}$$

Prices of intermediate commodities enter into output prices by sector, using the adding up principle—see Eq. (15). This closes the cost-price circle.

A number of other market price deflators can be calculated. The most important is the link between gross value added and private consumption. Deflation takes place from two sides.

From the side of production, gross value added is transformed to disposable income by deducting transport costs related to commuting and from the demand side by deducting transport costs related to shopping from commodity market prices by place of demand.

In the case of production and income, disposable income in current prices is calculated as follows:

$$H^{T,C} = ((i^R)'(PHK^{R,T} \;\#H^{R,T,C} P\hat{H}^R - U_{V=\text{tr,commuting},CP}^{R,T,C}))' \tag{25}$$

From the demand side, private consumption in current prices by place of residence can be calculated as follows:

$$U_{CP}^{T,C} = (PUK_{CP}^{S,T} \;\#U_{CP}^{S,T} P\hat{U}_{CP}^S - U_{V=\text{tr,shopping},CP}^{T,S,C}) i^S \tag{26a}$$

The implicit price index for private consumption by place of residence can now be determined:

$$PU_{CP}^T = U_{CP}^{T,C} / U_{CP}^T \tag{26b}$$

$$PU_{CP,\text{TOTAL}}^T = (i'U_{CP}^{T,C})(i'U_{CP}^T) \tag{26c}$$

5.7. Production in the transport sector—current prices

In calculation of production in current prices, demand for transport commodities in current prices enters. Calculation of purchase of transport commodities in current prices is carried out by multiplying purchase of transport commodity in fixed prices (for example in Eqs. (13a), (13b), (13c) and (13d)) by a price index for transport commodities obtaining demand for transport commodities in current prices (Eqs. (21a), (22a) and (25)). The demand for transport commodities in current prices and the price index for transport commodities are calculated in a similar way to the corresponding variables for other commodities. The point of departure is the production price index in the transport sector (and other transport commodity producing sectors), which is transformed into production in current prices and a price index for transport commodities, which in turn is transformed into commodity demand in current prices and a price index by place of demand for transport commodities.

5.8. Linking the cost-price and real circles in LINE

In the presentation of LINE above, the cost-price circle does not have impacts on the real circle. Changes in local costs and prices only have an impact on economic activity measured in current prices, but local economic activity in fixed prices remains unchanged. The road pricing study version (see study 8 in Table 1) does include the effect that changing consumer prices have on real disposable income using a price index.

This price index is used for deflating real disposable income:

$$H^{T} = H^{T,C} / PU^{T}_{CP,\mathrm{TOTAL}} \qquad (27)$$

In the version of the model used to analyse the Great Belt toll problem, the following links between the two circles have been established:

1. Private consumption in fixed prices, as a function of disposable income and prices by place of residence.
2. Export to abroad by commodity as a function of relative prices of domestic and foreign commodities.
3. Import from abroad as a share of demand, as a function of relative prices of foreign and Danish commodities.

In future model versions, incremental introduction of links between the two circles will provide a more complete and realistic picture of the effects of changes in the cost-price circle on the real circle. In an extended interregional general equilibrium model, cost and price changes also affect demand and supply in a number of different ways. On the supply side, productivity in a given region depends upon proximity to other regions, and wage level also depends on distance to work. Reduction of transport costs increases proximity and lowers wage costs. On the demand side, because of substitution effects, changes in the composition of private consumption depend on changes in relative prices. Changes in transport costs will, in the case of intra- and inter-regional trade, also affect the choice of place of production (between place of production and place of demand) and in the case of local private consumption and interregional tourism, the choice of place of demand will be affected (between place of residence and place of demand). The composition of intermediate consumption and place of demand for intermediate consumption will also depend on relative commodity prices. Further, investment depends on prices of investment goods.

Assumptions can also be introduced concerning the way in which the fixed link is to be financed when tolls disappear. This has been undertaken elsewhere (Madsen et al., 2002), though these results are not presented here. In an extended interregional general equilibrium model, it is assumed that institutions re-establish their economic balances in the long term through development of new behavioural relationships. For example, for households, savings are assumed to move to a steady state equilibrium and for governments, expenditure again equals revenue.

If both the substitution effect derived from the linkage between the real and cost-price circles and the financial reactions at the institutional level are included in the model, it is possible to use LINE both to illustrate the efficiency and distributional effects of trends in development and policy measures.

5.9. Solution routine

As described above, the model solves equations in two circles. Starting with Eq. (1) the equations of the real circle are solved until Eq. (12) is reached and the circle is closed. Then the equations of the cost-price circle are solved starting with Eq. (15) and moving anti-clockwise through the equations of the cost-price circle until Eq. (26) is reached, closing this circle. This permits modification of Eq. (2), using Eq. (27) for private consumption (with corresponding changes for exports and imports) and a new model cycle commences, reaching Eq. (12) again and returning to Eq. (26). These iterations continue until X^R in Eq. (12) and Eq. (1) becomes stable.

6. Results from the Great Belt toll study

Application of LINE permits analysis of the consequences for the regional economy of any change in the transport system, which affects the costs of transport. The change in transport costs examined, in this case the elimination of tolls for vehicles using the Great Belt fixed link has been described in Section 5.1 above.

The analysis begins in the interaction components of the cost-price circle shown in Fig. 2. Starting with trade in commodities (RV to SV), the prices of commodities decline. Given the point at which the analysis commences, the presentation follows the two circles, where first the effects on commodity prices are derived, followed by the real effects on demand, production, employment and income. For other cases (see Table 1) the starting point depends on the nature of the initial shock.

6.1. Changes in transport costs

The present version of LINE incorporates exogenously given interregional transport costs, based on a digital road map, *Vejnet DK*. Four different sets of travel costs are used for: (i) lorries, high value goods; (ii) lorries, low value goods; (iii) cars (high value: private and commercial use; and (iv) private cars: low value:

Table 5
Maximum speeds applied in the model

	Car	Lorry
Motorway	110 km/h	80 km/h
Non-urban highway	80 km/h	70 km/h
Urban	50 km/h or local restrictions taken from VejnetDK	Max 50 km/h or local restrictions if under 50 km/h

private use. Transport costs are based upon both time and distance where the generalised cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. The calculations are based on assumptions concerning maximum speeds shown in Table 5 and values of time as shown in Table 6.

These transport costs are transformed to demand for transport commodities in the National Accounts. In this transformation the distinction between high and low value commodities is maintained. Transport of commodities by lorry in relation to manufacturing is divided into trade in low value and high value products based upon the weight/value relationship, where low value goods have a high weight/value ratio. High value car transport is for commercial use (trade in services) and for private commuting, whilst low value car transport covers shopping and tourism. Further, differentiation is made between internal (own vehicle, excluding time costs) and external (transport purchased in the market, including time costs). This is undertaken both for households' and firms' transport costs.

Table 7 shows the consequences of reducing tolls on the Great Belt fixed link to zero. It is assumed that all ferry routes between East and West Denmark (see Fig. 4) will continue with unchanged ticket prices. The reason for this seemingly unrealistic assumption is that in the agreement concerning the construction of the Great Belt fixed link, a provision was made to maintain the ticket prices on ferry routes between East and West Denmark at a constant level. The losses in revenue for the ferry route operators are financed by the state.

Table 6
Kilometer-dependent costs and time costs used in the model (Dkr 7.50 = ca 1 Euro = ca 1$ US)

	Kilometer-dependent costs (Dkr/km)	Time costs (Dkr/h)
Car: high time value, commercial and private	1.80	199.00
Car: low time value, private	1.80	56.00
Lorry : high commodity value	1.99	192.00
Lorry: low commodity value	1.49	192.00

Table 7
Changes in transport costs (%) for transport between each Danish region and Copenhagen municipality assuming that the Great Belt tolls are set to zero

	Lorry				Car			
	High value		Low value		High value		Low value	
	External	Internal	External	Internal	External	Internal	External	Internal
Copenhagen M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frederiksb. M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copenhagen C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frederiksborg C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Roskilde C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vestsjællands C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Storstrøms C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bornholms C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fyns C	−52.4	−71.4	−55.1	−76.6	−20.3	−34.2	−28.6	−34.3
SønderjyllandsC	−38.7	−58.3	−41.5	−64.9	−13.2	−23.2	−19.2	−23.2
Ribe C	−37.8	−57.4	−40.6	−64.1	−12.9	−22.6	−18.6	−22.6
Vejle C	−43.2	−62.8	−46.1	−69.0	−15.4	−26.5	−22.1	−26.7
Ringkøbing C	−36.9	−57.0	−39.5	−63.7	−12.1	−22.3	−13.8	53.8
Århus C	−37.3	−56.9	−40.0	−63.6	−2.9	131.8	0.0	0.0
Viborg C	−32.7	−52.8	−35.3	−59.7	−10.2	−19.6	−7.1	55.6
Nordjyllands C	−30.5	−49.4	−33.1	−56.4	−5.0	62.6	0.0	0.0

Note: The suffix M indicates municipality and C county. These two municipalities have county status.

Only trips that cross the Great Belt experience a reduction in transport costs. Cost reductions are greatest for regions close to the fixed link and less for regions further away. Cost reductions are also greater for lorries than for cars and they are greater for low value lorry and car transport as compared with high valve transport. Transport costs in relation to external transport, which also includes time-savings, are reduced more as compared with internal transport costs, which in some cases actually grow. This is explained by a shift in transport corridor from the ferries to the fixed link (see Fig. 4), which increases the kilometer-related costs even though time costs decline. This means that the internal costs increase and the external costs decline. Time-savings related to a change in route choice, now using the fixed Great Belt link, cover the increase in direct transport costs more and, therefore, this route becomes attractive for households, even though the monetary transport costs increase.

The reason why there are large positive values for car/high value/internal for Aarhus and Nordjylland is that distances increase markedly with a shift from ferry to road and the Great Belt link. In the case of car/low value/external and internal for Nordjylland the zeros indicate continued use of ferries.

6.2. Changes in commodity prices and disposable incomes

In Table 8, column 1 shows in general that prices fall at national level by 0.20% for demand for commodities produced domestically.

Table 8
Price changes for demand and production, export, import and private consumption by place of residence and place of demand with tolls set to zero. Percentages

	(1) Demand: domestic production (SV)	(2) Demand (SV)	(3) Intermediate consumption (RE)	(4) Gross output (RE)	(5) Foreign export (RV)	(6) Foreign import (RV)	(7) Private consumption. Place of demand (SW)	(8) Private consumption. Place of residence (TH)
Copenhagen M	−0.28	−0.21	−0.24	−0.14	−0.15	0.28	−0.27	−0.26
Frederiksberg M	−0.31	−0.25	−0.28	−0.13	−0.27	0.31	−0.27	−0.26
Copenhagen C.	−0.26	−0.20	−0.25	−0.14	−0.23	0.26	−0.17	−0.26
Frederiksborg C	−0.29	−0.22	−0.29	−0.15	−0.25	0.29	−0.20	−0.27
Roskilde C	−0.22	−0.17	−0.21	−0.12	−0.17	0.22	−0.16	−0.30
Vestsjælland C	−0.26	−0.20	−0.25	−0.16	−0.18	0.26	0.15	−0.65
Storstrøm C	−0.12	−0.09	−0.10	−0.07	−0.07	0.12	−0.09	0.00
Bornholm C	−0.19	−0.16	−0.20	−0.11	−0.15	0.19	−0.13	−0.11
Fyn C	−0.17	−0.13	−0.13	−0.09	−0.10	0.17	−0.10	−0.43
Sønderjylland C	−0.24	−0.18	−0.18	−0.12	−0.14	0.24	−0.16	−0.17
Ribe C	−0.19	−0.15	−0.14	−0.10	−0.12	0.19	0.11	−0.14
Vejle C	−0.16	−0.12	−0.12	−0.09	−0.09	0.16	−0.09	−0.18
Ringkøbing C	−0.24	−0.18	−0.17	−0.12	−0.14	0.24	0.15	−0.10
Århus C	−0.05	−0.04	−0.06	−0.05	−0.05	0.05	−0.04	0.05
Viborg C	−0.19	−0.15	−0.15	−0.10	−0.12	0.19	−0.11	−0.07
Nordjylland C	−0.07	−0.05	−0.07	−0.05	−0.05	0.07	−0.06	−0.05
Denmark	−0.20	−0.15	−0.17	−0.11	−0.13	0.20	−0.13	−0.20

Greater Copenhagen (Copenhagen M, Frederiksberg M, Copenhagen C, Frederiksborg C, Roskilde C) and Vestsjælland C experience greater price declines, whilst the more peripheral Århus C and Nordjylland C experience much smaller declines in price. The relative peripherality and weak industrial structure of Storstrøm C also result in small price declines here. Sønderjylland C and Ringkøbing C experience above average declines, whilst Fyn C, Vejle C and Viborg C have substantial, but below average declines. These changes reflect both the relative importance of the reduction in transport costs and regional specialisation where the resulting trade pattern means that, in general, industrial products are transported to the east by lorry, whilst high value service is transported by car to the west from Greater Copenhagen.

Import prices are not affected by the elimination of tolls, as it is assumed that imported commodities do not cross the Great Belt on their way to the Danish market. This means that prices for the total demand (column 2) only fall by 0.15% at national level whilst the regional distribution of price decline has the same patterns as demand for domestic products.

Column 3 shows that prices for intermediate consumption are affected by the reduction in transport costs, where Greater Copenhagen again experiences the biggest declines and Århus and Nordjylland the smallest. These changes affect prices of gross output (column 4); though their effect is smaller as intermediate consumption is only a part of gross output.

Column 5 shows that export prices relative to foreign prices fall by 0.13%, again most in Greater Copenhagen and least in Århus and Nordjylland. The regional pattern is similar to that in column 1 and for the same reasons. The foreign import prices are constant, which means that the price increases shown in column 6 arise because of price reductions for Danish produced goods. This column has the same pattern as column 1, but with the opposite sign.

Column 7 shows private consumption by place of demand, and exhibits a similar structure to the previous columns in the table. However, when private consumption by place of residence is examined (column 8), significant changes appear, because of changes in the cost of trips for shopping across the Great Belt, trips to visit family and friends, cultural and recreational visits, as well as tourist trips. There are now substantial price reductions in Vestsjælland, Fyn and their neighbouring regions, Roskilde, Copenhagen C and Vejle.

6.3. Changes in demand, production and income

In Table 9, column 1 shows the consequences for disposable income (in current prices) of the reductions in transport costs which affect commuting. As most commuting is towards Copenhagen, the principal increases are to be found in Fyn and Vejle with a limited effect in Sønderjylland and Ribe.

The decreases in disposable income registered for Århus and Nordjylland arise because the internal transport costs increase (own transport), despite time cost gains. Column 2 shows how disposable income changes if price reductions on commodities are also included. The effect is almost identical to that for private consumption by

Table 9
Consequences for demand, production and income with tolls set to zero. Percentage changes

	(1) Disposable income (current prices) (TH)	(2) Real disposable income (TH)	(3) Private consumptn: Place of residence (TW)	(4) Private consumptn: Place of demand (SW)	(5) Foreign imports (SV)	(6) Foreign exports (RV)	(7) Gross output (RE)	(8) GDP at factor prices (RG)
Copenhagen M	0.02	0.30	0.30	0.36	−0.20	0.18	0.18	0.15
Frederiksberg M	0.05	0.31	0.31	0.35	−0.19	0.76	0.26	0.20
Copenhagen C.	0.04	0.39	0.39	0.35	−0.27	0.58	0.31	0.22
Frederiksborg C	0.05	0.39	0.39	0.37	−0.32	0.52	0.34	0.25
Roskilde C	0.04	0.32	0.32	0.38	−0.10	0.42	0.34	0.25
Vestsjælland C	0.06	0.71	0.71	0.46	−0.06	0.41	0.40	0.28
Storstrøm C	0.06	0.05	0.05	0.28	0.10	0.15	0.26	0.18
Bornholm C	0.02	0.13	0.13	0.18	−0.17	0.28	0.22	0.14
Fyn C	0.15	0.61	0.61	0.52	0.14	0.21	0.31	0.24
Sønderjylland C	0.07	0.37	0.37	0.37	−0.04	0.25	0.33	0.24
Ribe C	0.07	0.33	0.33	0.31	0.12	0.27	0.33	0.22
Vejle C	0.12	0.42	0.42	0.31	0.11	0.19	0.31	0.20
Ringkøbing C	0.01	0.20	0.20	0.21	−0.05	0.32	0.31	0.19
Århus C	−0.05	−0.01	−0.01	0.11	0.01	0.10	0.24	0.15
Viborg C	0.02	0.13	0.13	0.14	0.09	0.24	0.30	0.18
Nordjylland C	−0.04	0.08	0.08	0.10	−0.13	0.08	0.17	0.10
Denmark	0.04	0.30	0.03	0.30	−0.07	0.27	0.27	0.19

place of residence (column 3). Here again, Vestsjælland and Fyn benefit most, but Greater Copenhagen, Vejle, Ribe and Sønderjylland also experience significant increases. Again, Nordjylland and Århus fare badly. Column 4 shows the increase in private consumption by place of demand, reflecting the more even spread of the effects noted in column 3 through shopping trips. Column 5 shows that overall import declines by 0.07%, reflecting two opposing tendencies. First, increased economic activity will tend to increase imports and, therefore, welfare gains arise even though disposable income decreases. Second, improved competitiveness, as the price of Danish produced commodities falls, will tend to reduce imports. The second effect tends to dominate the first. This means that the regions which experience the biggest improvements in competitiveness experience the biggest declines in imports, but that the pattern is also somewhat unclear because of the first effect. Column 6 shows the effects on exports of both the price decreases for export noted in Table 8 and the regional commodity export composition, as different commodities have different price elasticities. LINE uses the national import and export price elasticities used in Statistics Denmarks National Macro-Economic Model, ADAM (Dam, 1995). Column 7 shows the effects on Gross Output, where at national level Gross Output increases by 0.27%. The biggest increases are in the regions adjacent to the Great Belt and Greater Copenhagen, except for Copenhagen municipality, where it is more limited. Århus and Nordjylland are again the weakest performers. Column 8 shows GDP at factor prices. Here, growth is at a lower level

Table 10
Impacts on employment and disposable income with tolls set to zero

	(1) Employment at place of production (RG)		(2) Employment at place of residence (TG)		(3) Primary income (TG)	(4) Income transfers (TG)	(5) Taxes (TG)	(6) Disposable income (TG)
	- pct. -	number	- pct -	number	--- percentage ---		--- percentage ---	
Copenhagen M	0.17	552	0.19	487	0.15	−0.27	0.07	0.02
Frederiksberg M	0.20	79	0.20	96	0.16	−0.28	0.09	0.05
Copenhagen C.	0.23	843	0.22	679	0.19	−0.47	0.10	0.04
Frederiksborg C	0.26	396	0.24	466	0.24	−0.70	0.13	0.05
Roskilde C	0.25	243	0.23	303	0.19	−0.63	0.10	0.04
Vestsjælland C	0.28	367	0.27	393	0.47	−1.08	0.21	0.06
Storstrøm C	0.19	208	0.20	245	0.35	−0.59	0.18	0.06
Bornholm C	0.17	35	0.17	35	0.14	−0.24	0.06	0.02
Fyn C	0.25	563	0.25	575	0.84	−1.61	0.43	0.15
Sønderjylland C	0.26	335	0.26	334	0.50	−1.22	0.22	0.07
Ribe C	0.24	295	0.24	284	0.49	−1.30	0.23	0.07
Vejle C	0.23	415	0.23	412	0.67	−1.66	0.34	0.12
Ringkøbing C	0.24	353	0.24	347	0.34	−1.20	0.11	0.01
Århus C	0.16	531	0.17	551	−0.34	0.82	−0.16	−0.05
Viborg C	0.23	275	0.22	271	0.26	−0.75	0.09	0.02
Nordjylland C	0.12	292	0.12	303	−0.27	0.63	−0.12	−0.04
Denmark	0.21	5782	0.21	5782	0.23	−0.54	0.11	0.04

than is the case for Gross Output, but the regional pattern of growth follows that in column 7.

6.4. Changes in employment and income

In Table 10 column 1 shows that employment grows by 5782 (by place of production). The distribution of these employment increases follows closely the distribution of increases in Gross Output from Table 9. Fyn and Vestsjælland experience the biggest percentage increases in employment followed by parts of Greater Copenhagen. It should be remembered that service industries are over-represented in Greater Copenhagen and that these industries, where the use of the car is important, do not have as great an advantage from the changes in tolls as regions with industrial production using lorries for transport of commodities. Hence, the overall performance of Greater Copenhagen is close to the national average. In column 2 employment increases by place of residence are shown. This column exhibits the same basic pattern as column 1, the main difference being a more even increase in Greater Copenhagen, where commuting tends to distribute the effects of employment increases in spatial terms more evenly. Column 3 shows the consequences for earned income (wages and salaries plus surplus on self employment) that increases markedly in the areas, which gain from lower commuting costs over the Great Belt (Fyn and Vejle). Commuting is largely to Copenhagen, whilst in the opposite direction it is limited. These gains are modified by increased tax payments, (column 5) as transport costs to and from place of work are tax deductible. Changes in transfer incomes (column 4) further modify the pattern of income change. Declines in transfer incomes are, other things being equal, greatest in the regions where employment grows fastest.

Column 6 shows the net result of these changes on disposable income. Fyn and Vejle achieve the greatest increases, whilst Nordjylland and Århus have a decline in nominal disposable income. The other regions are close to the national average increase.

This final result means, that in modelling terms, we are now once again back at real disposable income in the real circle of the model (see column 1 in Table 8).

6.5. Changes in tax revenue

The full study involves even more analyses than those, which, because of space limitations, have been presented here. An additional question dealt with is the way in which elimination of tolls affect taxation. The elimination of tolls means that the public sector's budget deficit will grow and if this is financed by raising taxation, there will be a series of consequences for economic activity and disposable income, which have national and regional effects.

There are a number of different options available to finance the deficit which arises. These include:

- Increasing fuel taxation
- Increasing vehicle registration tax
- Increasing commodity taxes:
  - a VAT
  - b Specific commodity taxes
- Increasing income tax:
  - a High income band
  - b Low income band
- Reduction in public expenditure

Each option will have different total and regional effects.

In concrete terms, the study assumes an increase in the tax rate in the lower band of 1 billion DKR per year, which, though being a round figure, is approximately equal to the deficit. This increase in taxation reduces disposable income and private consumption, which in turn reduces demand, production and employment from the original increase in employment of 5782 to 3909.

In geographical terms, the effects on disposable income and private consumption of this increase in taxation will be relatively even, as the lowest tax band has been used. Other taxation options would create different geographical patterns.

Likewise, improved competitiveness will create a surplus on the trade balance, which in the long run, however, may disappear through exchange rate adjustments, Denmark being outside the Eurozone. If Denmark becomes a part of the Eurozone or if the present policy of a fixed exchange rate in relation to the Euro is successfully maintained, automatic adjustments will eventually occur in the labour market through downward adjustment of wages.

7. Limitations of the model and future development strategies

A central problem faced by input–output or more general demand-side approaches to regional economic analysis is the influence of supply side conditions on production, this being a primary concern of CGE approaches. Another set of problems relates to some of the central concerns of contemporary urban and regional analysis: the existence of imperfect competition; externalities; product variety and growth in productivity, all of which in a modelling context usually involve non-linear functional forms. In its present form, LINE builds on linear relationships. This raises the question of the suitability of LINE to deal with such issues.

In relation to the issue of supply-side conditions, as noted above, development of appropriate links between the real circle and the cost-price circle is the way forward. The Great Belt toll study illustrates the first step, where links have been established between relevant prices and disposable income, foreign exports and imports. In addition, the public sector's budget and finance problems have been considered. A future strategy involves development of similar links, for example, in relation to labour participation and productivity, or relating changes in commodity prices to the commodity composition of demand. Adjustments to changes in trade balances can also be included. The basis for this relation is the establishment of equilibrium in both commodity and factor markets and a steady-state equilibrium for institutional balances. When links between the two circles are expanded, LINE can be used to analyse efficiency and distributional effects of development trends and policy.

Even though this modelling strategy is similar to mainstream CGE approaches, the development of LINE nevertheless deviates from such CGE approaches to regional and interregional modelling. Both approaches are consistent with established economic theory and ensure equilibria with respect to markets and institutional balances. However, the mathematical complexity involved in the typical CGE approaches, which are often based upon non-linear functional forms, is attained at the expense of detail in the treatment of the regional and local economy. Thus, mainstream approaches, despite theoretical sophistication and complex non-linear mathematics, face severe problems related to lack of detail and a sound empirical foundation. They also frequently involve serious problems of calibration and solution.

One way of dealing with these reservations is to set up a model development strategy, which involves the stepwise inclusion of behavioural components requiring non-linear functional forms. As described above, LINE can be developed in different ways. One important direction is further development of the links between the real circle and the cost-price circle, in order to model productivity, wage determination and labour force participation rates in the labour market and substitution and income effects in relation to commodity markets (private consumption, export, etc.). Another important direction is to model in greater detail the consequences of a change in the institutional balances, for example, changes in household saving and consumption behaviour. These development strategies will transform LINE into a more advanced CGE model, as these essentially non-linear relationships are included in a step-by-step manner.

It might appear that the two modelling approaches converge towards a similar solution, this being an ideal CGE model. However, in reality the model development strategy employed in LINE, involving basically a linear system, represents a fundamentally different strategy to that utilised by mainstream CGE modelling, where there are often non-linearities in the central model equations, which are solved simultaneously. This places substantial constraints on the number of different actors, markets and level of detail, which can be incorporated in the models. In LINE, the complexity of the regional and sub-regional economic systems, including the possibility of choosing an appropriate model configuration, is in focus, whereas the increased mathematical complexity of selected behavioural components will be introduced in a gradual manner.

8. Conclusion

The requirements faced by model-builders today are very diverse, determined by the great variety of problems faced by regions and local authorities, which is reflected in the variety of studies which they generate. The ideal modern modelling tool must be able to respond to this diversity of demands placed upon it. The aim of construction of LINE described above is to ensure a high degree of flexibility, achieved in the basic model structure, which involves an inter-regional SAM. On this foundation, it is possible to ensure flexibility in the following areas:

The model can be structured as either a sub-regional model, a regional model, or a combined model, as it includes both commodity markets and tourism, usually treated as regional phenomena, and labour markets, commuting and shopping which are typical sub-regional phenomena.

The overall model includes different types of agent which enter into a SAM, activities, factors, institutions, needs, commodities, which means that there is a degree of flexibility, involving the option of including either all accounts or a choice of accounts. For example, a model covering activities or commodities (a local production environment model) or a model covering institutions and needs (an extended shopping model) can be constructed.

Three basic types of location, place of production, place of residence and place of demand enter into the overall model. Choice of combination of type of locality permits specific problems to be addressed, such as a commuting model involving place of production and place of residence and a trade model involving place of production and place of demand.

The overall model involves a real circle and a cost-price circle. This permits development of a fixed price model by using the real circle alone or a general equilibrium model based upon links between the real circle and the cost-price circle.

Further, given the above more strategic modelling choices, even more flexibility can be introduced by choice of aggregation of categories of activities, factors, institutions, etc.

The paper describes LINE and its use in a number of studies. The configuration of the model and the aggregation of the SAM accounts used in analysis of the regional economic effects of elimination of tolls on the Great Belt fixed link are presented together with a summary of empirical results from the analysis. The magnitudes and directions of change are all realistic and theoretically defensible.

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Section 8:

A Systems Approach to Modelling the Regional Economic Effects of Road Pricing

Bjarne Madsen, Chris Jensen-Butler, Jacob Kronbak & Steen Leleur

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Abstract

In Denmark, there has been a substantial debate in recent years concerning the consequences of introducing road pricing. This chapter examines some of the regional economic consequences of the full implementation of a GIS-based road pricing system for all roads in Denmark. A Danish model system (MERGE) consisting of an Interregional General Equilibrium model, LINE, a national transport model (LTM model) and an environmental sub-model (TIC-MAP) are presented. LINE is used to make an initial analysis of the primary regional economic effects. In the first step, price changes as a result of road pricing are calculated. In the second step, changes in regional competitiveness affecting demand are calculated. In the final step, revenue from road pricing is re-entered in order to ensure institutional balance, and the effects on production, income and employment are calculated.

1. Introduction

As road traffic grows rapidly in Europe, the problems which it creates become increasingly serious. Congestion is a major problem in many European countries, largely, though certainly not exclusively, an urban phenomenon. The costs of congestion are considerable, perhaps in the magnitude of 2% of GDP (Gomez-Ibañez 1997, Mayeres & van Dender 2001). Environmental damage, both local and global, arising from transport-related emissions also represents a substantial and increasing cost, with potentially extremely costly though uncertain consequences. Both problems involve externalities and raise issues concerning the extent to which external costs can and should be internalised (Rothengatter 2000). A further problem is the cost of transport infrastructure provision, which is considerable, whilst its net benefits are difficult to calculate in the presence of externalities (Jansson 2000a). These issues are of course linked, as taxation of transport can both reduce some of the negative externalities, creating a welfare improvement, and it can also provide revenue for the construction of more transport infrastructure or a subsidy for public transport. Furthermore, revenues from taxation on transport can be used to reduce taxation on earned income, giving rise to a possible double dividend effect (Pearce 1991). Parry & Bento (2001) have recently claimed that recycling tax revenues into transport sector subsidy is markedly less efficient than using the tax revenues to reduce income tax.

There is growing interest in road pricing as a policy instrument directed at the solution of congestion problems, seen as one of a set of alternative measures (Button 1998, De Borger et al. 2001a) as well as being a measure which simultaneously addresses other problems. Road pricing can also be used to internalise environmental damage costs (Johansson-Stenman & Sterner 1998) and there are a number of important issues linking congestion pricing to road and transport infrastructure investment (McDonald 1995, Hau 1998).

Road pricing raises a range of questions, both theoretical and practical. The welfare implications of road pricing and the potential distortionary effects of taxation are the subject of discussion (see, for example, Arnott et al. 1994, Jansson 2000b, Hau 1998). There are four components of welfare in the transport market: consumer and producer surplus, tax revenues and external costs. Unlike many other markets, time costs must be taken into account when dealing with consumer and producer surpluses. In addition, different surpluses and costs fall typically on different groups. Furthermore, different transport sub-markets are interdependent. For example, reduced congestion through road pricing will increase consumer surplus for users of road-based public transport. Alternatively, improvement of rapid transit and metro systems will confer benefits on car users, through reduced congestion. The welfare gains of road pricing (Proost & van Dender 1998) seem to be superior to most other forms of regulation of congestion. However, efficiency issues are inextricably linked to the difficult problem of evaluation of social marginal costs. Practical problems are related to the technology to be employed in managing the system, particularly at the user interface, and to the problem of traffic diversion (McDonald 1995). These problems are, in turn, closely related to the recurrent theme of political and social acceptability (Jones 1998, Rietveld & Verhoef 1998, Larsen & Ostmoe 2001).

The European Union and many individual countries are moving towards road pricing as a key element in future transport policy (De Borger et al. 2001b). In Germany, road pricing for lorries on motorways using a GPS-based system was planned to be implemented in 2003, but it was delayed due to start-up problems of a technical nature. It is to be expected that a number of European countries will follow and that it will be expanded to cover all types of roads and possibly in the long term all types of vehicles. The European PROGRESS project has established experiments and demonstrations in road pricing systems in eight different European cities, including Copenhagen (Nielsen 2003, Herslund 2003 on the Danish AKTA sub-project). This increased political interest in road pricing is fuelling research interest in the field. A number of studies have attempted to assess the effects of road pricing on congestion, the environment, tax revenues and welfare in concrete geographical contexts (see De Borger & Proost 2001 for a number of case studies). The studies are usually *ex ante*, as only a few projects have actually been implemented and these are limited in extent and impact. Amongst others, Proost & van Dender (2001) have developed an urban model based upon a transport market equilibrium derived from the maximisation of a social welfare function which includes the four components named above, and which permits assessment of the effects of different policies on transport supply and demand.

Most of these studies treat transport as an independent commodity, while in reality it is derived demand. The spatial configuration of the economy and the development of spatial patterns of economic activity play a substantial role in the pattern and growth of transport activity. This means that road pricing will have effects both on the level and distribution of economic activity and, in turn, patterns of regional economic development will affect both the need for, and revenues from, road pricing. There are both efficiency and distributional issues when examining the relationship between road pricing and regional economic growth.

The relationship between transport infrastructure and regional economic development has been examined in a number of studies (see, for example, Rietveld & Nijkamp 2000, Jensen-Butler & Madsen 1999). Equity issues, directly related to the distribution of economic activity and population in space, have been the subject of some studies (for example, Richardson & Bae 1998). However, there have been few attempts (Madsen & Jensen-Butler 2001, 2002c) to include road pricing within a regional or interregional economic model and even fewer in the context of local economic modelling. Eliasson & Mattsson (2001) present one of the few attempts to relate road pricing to location and transport flows, using a simulation model for a city. They conclude that impacts on location seem to be modest, compared with impacts on traffic. In an empirical analysis using an interregional economic model and Danish data, Jensen-Butler & Madsen (1996) find evidence to suggest that environmental gains from distance-related taxation of transport far outweigh income loss.

The present paper is a contribution to the study of the regional economic effects of the introduction of road pricing, using Denmark as an empirical example. The two-stage approach adopted is to model the effects of road pricing on regional economies. The paper covers only the first stage, where a local economic model is used to forecast changes in commodity prices and household income, together with the effects on demand, as a consequence of the introduction of road pricing. At this stage of the modelling process, it is assumed that the underlying behavioural relationships are constant. The second stage, which is not dealt with in the present paper, is to incorporate changes in behavioural relations, transforming the modelling approach in the first stage to a Computable Interregional General Equilibrium model, permitting a more complete analysis of changes in prices on economic activity in a regional system.

2. A Systems Approach to Regional and Sub-Regional Economic Modelling

At different levels, international, national and regional, complex problems of analysis and planning of the relationships between specific sectors and the broader economy are emerging. One example of this complexity is the relationship between the transport sector, the broader economy and the environment. Another example is the relationship between agriculture, the economy and the environment. There are two fundamental issues to be examined when considering the nature of the relationship between a specific sector and the broader economy: i) data and accounting principles and ii) modelling approaches.

2.1. Data and Accounting Principles

Statistics and accounting aim to provide a picture of the complex system. At this level, either the complex system can be represented through a system of national/regional accounts together with satellite accounts for specific sectors, or it can be represented by sector-specific statistics which have been extended to include the broader economy. Principles for setting up national/regional accounts together with satellite accounts for specific sectors are provided by the United Nations (1993) and the European Union (Eurostat 1996). Similar activities are to be found at the sectoral level. The main advantage of the economic system approach is uniformity in statistical framework and, therefore, they are comparable and consistent with constraints. However, the basic units of accounting are value, rather than physical units, such as transport volumes and quantities of emissions. Description of physical units, where this appears, is highly aggregated. The main advantage of sector-specific approach is the level of detail with respect to physical components, whereas the value-based information in these accounts is more ad hoc, less consistent and highly aggregated.

At the regional and sub-regional levels, the statistical material available is much less developed than is the case for the national level. The statistics relating to the broader economy are based upon local social accounting matrices (SAMs) or local national accounts. Satellite accounts do not exist at this spatial level, except for tourism, where they are being developed at the present time. Sector-based statistics exist in the form of detailed accounts for agriculture and in the form of ad hoc data bases on transport flows in the case of the transport sector.

2.2. Modelling Principles

In terms of modelling, both in relation to the broader economy and individual sectors, several trends seem to be emerging. First, there is a growing interest in the interaction between the broader economy and specific sectors seen from the perspective of the broader economy. Second, modelling the interactions between specific sectors, such as agriculture and transport, and the broader economy, seen from the sectoral perspective, is developing. Broadly speaking, there are therefore two alternative modelling approaches. Economic system modelling involves modelling the economy as the core question, whilst sectors are treated as additions, usually as a front end or back end sub-model, and sometimes as an integrated element in the core model. In Denmark, examples are provided by models such as ADAM (Dam 1995) and AAGE (Frandsen et al. 1995) and in relation to transport see Fosgerau & Kveiborg (2003). Sector-specific modelling on the other hand has as a point of departure, a partial or free-standing model for the sector in question. This model is then usually extended to capture interactions with the broader economy. In Denmark, examples are provided by (Stryg et.al.1992, Hansen 2001 and Madsen 1999).

At the regional and sub-regional levels the same two issues arise, but in an even more complex form.

Stand-Alone Approaches

In relation to modelling activity, a number of analyses of the broader economy have been undertaken. Starting with straightforward single region Keynesian input-output models (Groes 1982, Madsen 1992a), interregional input-output models were developed (Holm 1984, Madsen 1992b) followed by interregional General Equilibrium models (Madsen et al. 2001a). Regional sector-specific models have been mainly concentrated in the agricultural and transport sectors. For agriculture, the approaches adopted have included input-output models (Pedersen 1986), linear programming models (Stryg et al. 1991) and econometric models (Jensen et al. 2001, Hansen 2001).

For the transport sector, a number of models have been developed (for an overview see: Madsen 1999). There is a national transport model as well as transport models which have been developed to analyse specific infrastructure investment projects, for example, the Femer Belt Link (Trafikministeriet 1999, Jensen-Butler & Madsen 1999) and the Øresund link (Øresundskonsortiet 1997) and upgrading or extending of existing rail networks, for example the Ringsted model (Nielsen 1998).

A traditional approach and fundamentally stand-alone approach involves the identification of changes in transport flows and changes in direct and indirect (time) costs for travellers. This information is then used to undertake a cost-benefit analysis of the changes in the regulation of the transport system, involving an evaluation of changes in direct costs, time savings and changes in other costs, such as accidents and environmental costs. Normally, the diffusion of changes in the costs of the transport sector to commodity prices and incomes in other sectors is not dealt with. This means that the traditional cost-benefit approach cannot be used for analysis of distributional questions in relation to regions, factors, sectors and household types. In addition, as behavioural reactions from producers and consumers are not included explicitly in the cost-benefit approach, determination of the value of time for different categories of traveller is made exogenously rather than endogenously.

Different Approaches to Model Integration

Treating the general economy and the specific sector as two independent components is theoretically less than satisfactory, as development of the individual sector is partially dependent upon the general economic development and vice-versa. Therefore, there is a need to develop a more integrated approach to the problem.

Four avenues in the development of integrated models at the regional and sub-regional levels are identifiable.

- Extension of sector-specific models
- Extension of regional and sub-regional models
- Loosely coupled models (framework approach)
- Fully integrated models

The first can be illustrated by the extension of models specific to the transport sector with regional and macroeconomic elements. An important representative of this approach is use of the established growth factor model in forecasting total traffic flows. For passenger transport, attempts have been made to develop strategic models which include more developed modelling of interaction between the transport system and the broader regional economy including migration and commuting flows (Husted & Christensen 2001).

The second avenue is represented by the extension of regional and sub-regional models of economic activity to include specific sectors, again typically transport. In the case of the Great Belt Link (Jensen-Butler & Madsen 1996), the analysis included not only the effects of the establishment of the Great Belt Link on regional economic activity (employment and GDP by region), but also an analysis of the consequences for structural change in interregional trade patterns. In the case of the Femer Belt Link (Jensen-Butler & Madsen 1999), a simple transport model was incorporated into the analysis to estimate the shifts in traffic flows by transport corridor in order to estimate the redistribution of regional economic activity.

The third avenue is based upon a different modelling strategy, where economic models and sector models are linked together in a loosely coupled framework, consisting of separate and independent models linked together inside a general framework. Loose coupling implies that the models are independent, but that output from one model constitutes a data input to another. This strategy has developed most strongly in the agricultural sector. In an initial attempt to evaluate the regional economic consequences of restructuring the European Union's agricultural policy in 1991 (the McSharry proposal), the results emerging from an agricultural sector model (Stryg et al. 1992), consisting of changes in gross value added (GVA), other taxes linked to production, employment together with estimates of impacts on the food industry, all by region, were taken as inputs to the single region model EMIL (Madsen 1992a).

This contrasts with an integrated model, where the different sub-models are solved simultaneously constituting a fourth avenue. Here, one single model user has an overview of the entire system.

2.3. Optimal Model Structure

The optimal model structure depends on both the nature of the object of analysis and the analytical capacity of the model users. If the focus is on a specific sector, then the choice of a specific sector model (a partial model) should be made. Here, it is assumed that the key parameters required for the operation of the model are supplied unambiguously (for example, the inputs of a growth factor model to a transport model). Alternatively, if it is assumed that there are strong interactions between the specific sector and the general economy, then it is necessary to integrate the models. The two basic forms of integration can, as mentioned above, be described as loosely coupled models or fully integrated models. In the case of transport and agriculture, loose coupling is more appropriate here, whilst in the case of the public sector and of tourism an integrated approach is more relevant. This is because the transport and agriculture sectors are complex, requiring a special modelling approach, which makes it necessary to build up specific models for each of the two sectors reflecting the complexity of the technical relations involved. Analysis of tourism and the public sector involves lower levels of technical specification, being more directly based on the conventional theory and models of consumption and production.

An important requirement for the loose coupling of models is that they rest on the same or a very similar theoretical foundation. In addition, there has to be consistency in exogenously given assumptions and parameters. Also, practical considerations related to the fact that single research groups only cover specific areas and model sets promotes the use of loose coupling.

2.4. A Loosely Coupled Model for Transport and Agriculture

On the basis of the above discussion, a combination of a fully integrated and a loosely coupled modelling system has been developed and used in a number of studies of the interaction between developments in specific sectors and regional economies in Denmark, also including interactions between international, national and local levels. The model system is presented in figure 1. The horizontal dimension shows in the centre general (equilibrium) models for the entire economy whilst to the right and left at this level the specific sectoral models (for agriculture and transport) are shown, which are loosely coupled together with the general models. Tourism and the public sector are, however, fully integrated models to be found in the centre of the figure.

The vertical dimension shows the different levels of spatial resolution from the international level to the sub-municipality level. Each box represents an independent model and the arrows between the boxes represent flows of data (results) between the models.

As can be seen from the figure, the total model system has been developed on a top-down principle, starting with a model of the international economy, GTAP, (Bach et al. 2000) to estimate the equilibrium values of central variables in the international economy, for example gross output, disposable income, aggregate demand, imports and exports. On this basis, the model for the national economy, AAGE, (Frandsen et al. 1995) determines equilibrium values for the Danish economy, including national values for the agricultural sector. The links between the economic model and the agricultural model and between the international, national and local level models are documented in Hasler et al. (2002). The link between the economic model and the transport model is documented in Kronbak & Leleur (2003) and in this paper.

The economic model, LINE, is linked to the models for the transport sector by an interaction model, MERGE (Kronbak 2002). MERGE not only links the models in the general economic sector with the models in the transport sector, but also links the models within the transport sector together. The models used in the transport sector are the environmental impact model TicMap (Wass-Nielsen & Hviid Steen 2001), the transport model TSM and the assessment model COSIMA (Leleur et. al. 2005).

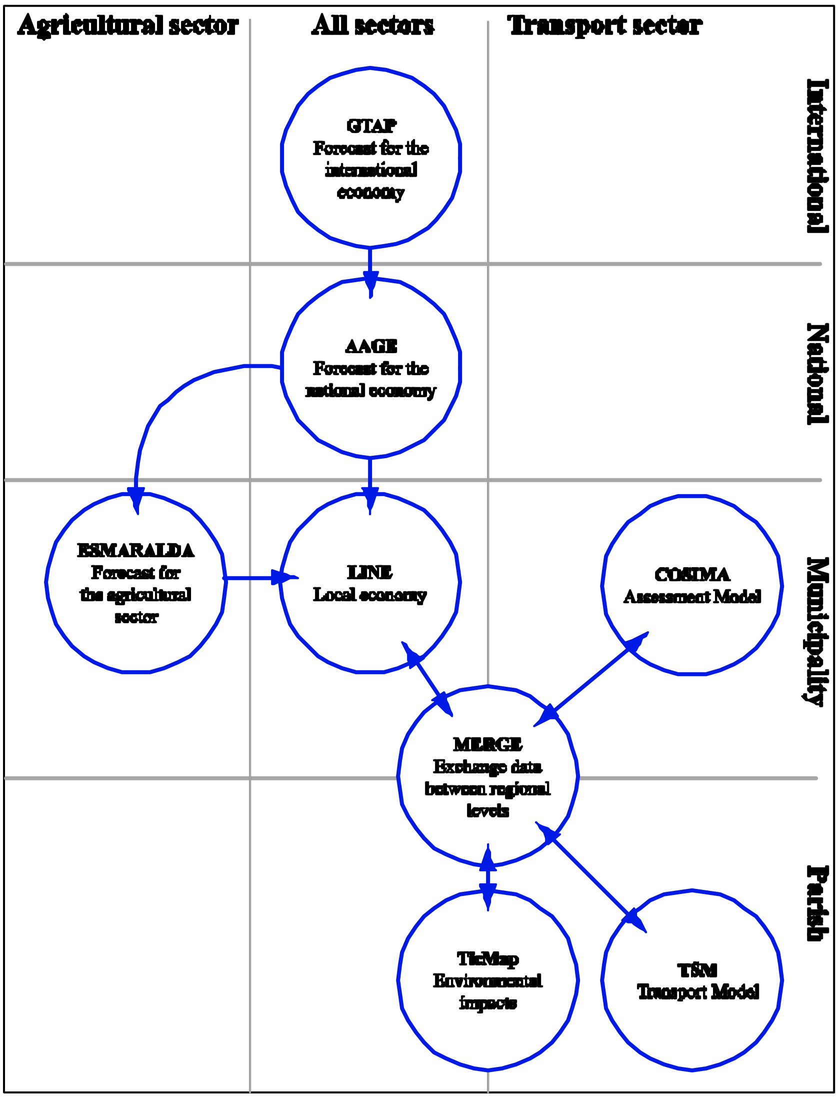

Figure 1. Linking Danish models of different types and levels

3. The Linking Procedures

The linking procedures are described in a bottom-up way where first the linking of models within the transport sector is dealt with and second the linking of the transport and the regional economic models. By giving some detailed information about the individual model elements, the potential of comprehensive modelling on the basis of the suggested systems approach – also for other types of examination than road pricing – is more easily apprehended.

3.1. Linking the Models within the Transport Sector

The models within the transport sector are connected using a geographical information system as linkage. This GIS-based linkage has been named MERGE (Model for Exchanging Regionalised Geographic Entities).

MERGE

The keyword in MERGE is model integration. Within the transport sector, MERGE has to link the transport, environmental impact and assessment models together into a decision-making tool by making procedures for transferring input and output data between the models. Besides that, MERGE also has to make the linkage between the models in the transport sector and the interregional economic model (LINE).

For each type of model within the transport sector, an existing model has been chosen for the decision-making tool:

- The Transport Sketch Model, TSM, developed at the Centre for Traffic and Transport, Technical University of Denmark.
- The environmental and economic impact assessment tool TicMap, developed at the Centre for Traffic and Transport, Technical University of Denmark.
- The Composite Model for Assessment (COSIMA) developed at the Centre for Traffic and Transport, Technical University of Denmark.

The integration of these models has addressed some questions that are not only relevant for the specific models in question, but it also has a more general application. This means that some of the procedures developed in MERGE are quite universal for loosely coupled model integration. As for most loosely coupled models, the starting point for MERGE has been a more general approach to model integration (including data transfer) and from there on to focus on the specific models.

This approach has had the advantage that if/when other (or better) models become available, they can be utilised with less effort than if MERGE was specifically designed for the models mentioned in a fully integrated model. This can be referred to as model modularity and the principle is that other models can be "snapped" on to MERGE and used in coherence with the total modelling framework.

Besides the modularity of MERGE, another important factor in the loosely coupled model integration has been consistency. One of the objectives of MERGE has been to provide data exchange between the transport, impact and assessment models (and also to the regional economic model). All these types of models rely to a certain extent on spatially distributed data, but not necessarily on data with the same spatial distribution or level of aggregation. When integrating the models into a decision support system, it is important to ensure a common consistent basis so that results and conditions are identical or at least consistent to some extent. It is especially important to be able to reproduce results and datasets.

An example is that if a model requires 50 zones, MERGE has to be able to generate this number of zones, preferably from any base dataset, under a number of different conditions, e.g. equal number of inhabitants within the zone; equal area of the zones, etc. At the same time, it has to be possible to keep track of where data originated from and to give some estimates of the accuracy of not only the original data, but also of the generated data. This is commonly known as metadata (or data on data).

Generation of new datasets from an existing dataset is where GIS has proven to be a very powerful tool. Results and input data all have some kind of spatial attributes, e.g. population data can be at a municipal or a parish level. It is not necessary that all the integrated models actually use the spatial reference, but the spatial reference can be used in MERGE to generate and exchange datasets.

Transport Sketch Model (TSM)

The TSM is a more or less traditional 4-step traffic model. Some of the advantages of this model are that it is already fully integrated in a GIS (ArcInfo) and since it is conceptually simple, it runs fast – even on large networks. Although national and regional individual road transport is at the focus of the model, it also provides an assessment of transport by rail, bus and ferry in Denmark.

Traffic Impact and Cost Mapping (TicMap)

The TicMap model (Wass-Nielsen & Hviid Steen 2001) is a tool for traffic impact calculation. The basis of TicMap is four GIS-based impact models for:

1. Accidents
2. Noise
3. Emission
4. Severance and perceived risk

Each of these impact models is based on Danish impact assessment models and can be run individually from within the geographical information system (MapInfo).

The results from the impact models are used to make an assessment of the impacts on each road segment in the network. For a closer description of the impact models, see for example Wass-Nielsen & Hviid Steen (2001), Clausen et al. (1991) or Leleur (2000).

Composite Model for Assessment (COSIMA)

The COSIMA model has been worked out to provide a more comprehensive assessment of transport initiatives than made possible by applying a conventional cost-benefit analysis (CBA). Thereby, COSIMA deals with a mix of CBA effects and non-CBA effects. Typically, the non-CBA effects – when seen from a modelling viewpoint – are more difficult to handle compared to the CBA effects where handbook approaches (pricing and procedures) are available for many transport planning problems. In brief, one can refer to the CBA effects as effects where pricing manuals and procedures exist and to the non-CBA effects as multi-criteria analysis (MCA) effects as this type of analysis, stemming from operations research, becomes relevant for the extension of the conventional CBA. The idea of COSIMA can be described briefly by the following seven steps as formulated for the assessment of a number of alternative by-pass projects for a Danish town currently in need of relieving the through traffic (Leleur 2001).

1. The first task is to determine the CBA effects being relevant for the concrete appraisal study. In the by-pass example, following the Danish Road Directorate's standard model, the effects are: travelling time, vehicle operating costs, accidents, maintenance costs, noise, air pollution and severance & perceived risk. The investment enters the analysis denominated as the construction costs.
2. The next task is to determine the MCA effects of relevance. These may be measured either in some type of quantitative unit, an example could be changes in strategic mobility see Kronbak (1998), or by judgement using a +5, .., 0, .., -5 scale. Three possible MCA effects of relevance for many Danish road projects are: network accessibility, urban planning and landscape.
3. With CBA and MCA effects laid down, the so-called "anchoring" part of the model formulation can take place. This means determining the importance of the MCA effects against the CBA effects and in-between each other. Several MCA techniques are relevant here: direct weights, pairwise comparison, swing weights, etc., see Leleur (2000). Criteria importance is denominated by weights on the individual criteria adding up to 100%.
4. At this stage, a base case scenario is modelled and presented to the decision-makers together with the assumed interesting assessment questions; these concern issues that may have a principal influence on the decisions to be made from the study. The involvement of the decision-makers may lead to revision of both the kind of MCA impacts included and

their weights in the base case scenario. Part of this exchange with decision-makers is also to formulate suitable additional scenarios.

5. Afterwards, COSIMA is run for all the scenarios and the assessment questions are scrutinised and related to possible sources of uncertainty. This "deterministic run" of the model and the identification of "varying levels" of information give intermediate results which are examined in the following model step as concerns their "feasibility risks" which indicate that a result in the deterministic run may be associated with such uncertainty that precaution is needed.
6. Next, the so-called "stochastic run" of COSIMA is undertaken. This in fact is a Monte Carlo simulation where parameters and data have been replaced with suitable probability distributions that can represent the actual information level. In the by-pass example used as background for this overview of steps in COSIMA, use is made of both distributions arrived at empirically by data fitting and distributions set on the basis of reasoning. One could refer to those as "objective" and "subjective" probability assessments.
7. At this stage, the assessment questions are addressed on the basis of the model results and the assumptions in the background and a second exchange with the decision-makers is carried out. With the layout of the COSIMA model as a transparent tool box, two principal possibilities are now available. The study may simply end here if the decision-makers are confident about the model outcome, or the decision-makers may want to feed back into the process and re-address some of the previous model settings to shed light on some issues.

It should be noted that COSIMA is more or less tailored dependent on the concrete application. As should appear from the overview of methodological steps above, features for applying both scenarios and risk examinations are available. When incorporating COSIMA in the MERGE model software, the way the other three model categories are set for the actual planning problem will influence the possibilities for the assessment analyses to be carried out in the COSIMA module.

3.2. Linking the Transport and Regional Economic Models

The role of transport costs and the transport system are integrated into LINE, though the integration is still incomplete. In LINE, supply and demand for transport are modelled in a full and consistent manner, while transport in physical terms has not yet been modelled. Transport costs and transport system changes feed into the present version of LINE in an ad hoc way and the effects of changes in the local and regional economy on traffic flows are not yet modelled explicitly. In order to illustrate the division of labour between transport models and regional economic models in a fully developed modelling framework, an idealised set of relationships between LINE and a standard sequential transport model can be seen in figure 2.

The linked model is simultaneous as there are linkages in both directions. Spatial interaction forms the link from the transport model (transport costs) to the regional economic model (to the cost-price circle) and from the regional economic model (interregional interaction, such as trade or shopping) to the transport model (to the real circle).

Compared with a traditional free-standing regional economic model, determination of transport costs takes place in the transport model, which replaces exogenous estimates of transport costs. In relation to a traditional free-standing sequential transport model (see, for example, Wilson et al. 1969), the economic model has replaced the trip generation, attraction and distribution steps by an economic model for interaction (trade, commuting etc.) and a model for trip frequency.

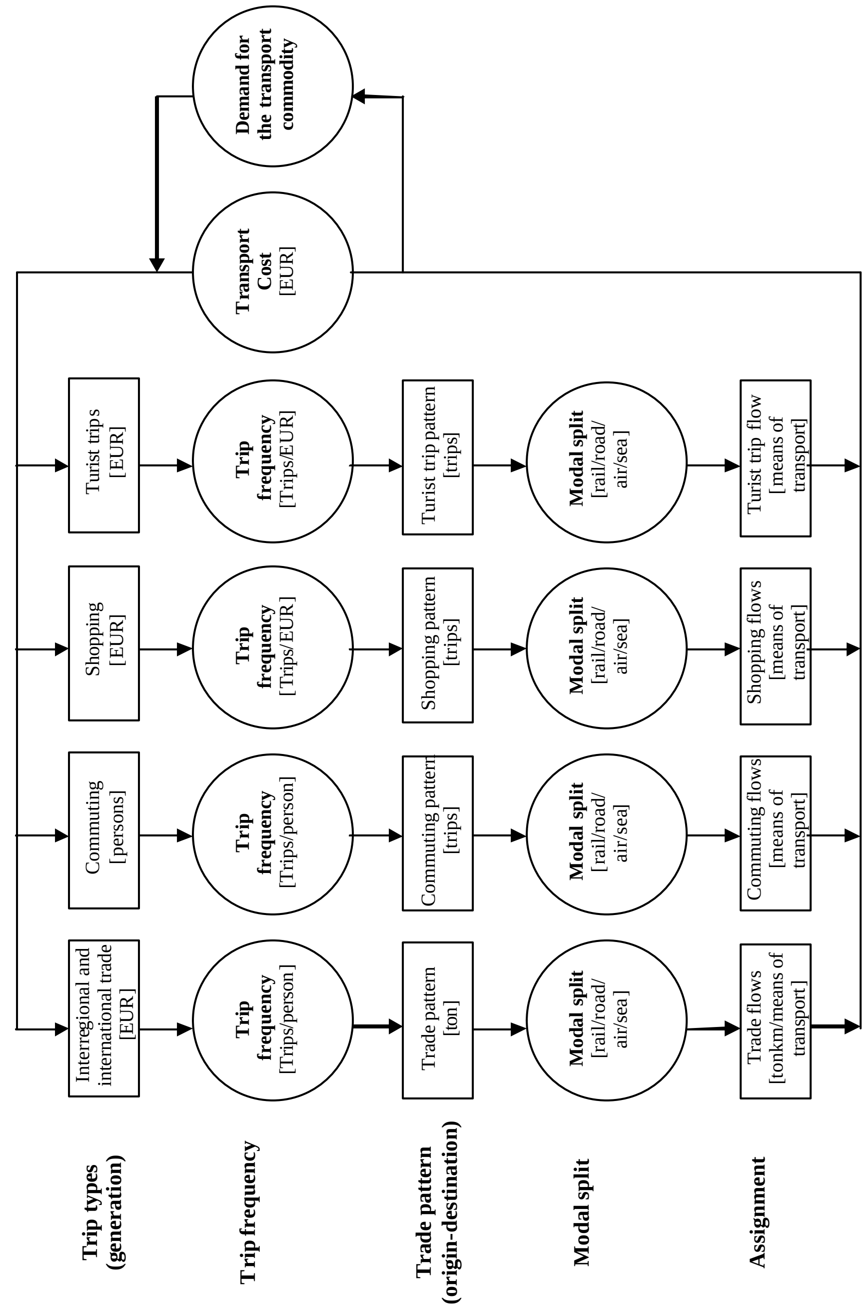

Figure 2. An idealised integrated model of transport and regional economic change

Transport Inside LINE

A number of features of the treatment of transport inside LINE are important. First, the model distinguishes between mobile and immobile commodities. Mobile commodities are transportable commodities whilst for immobile commodities, place of demand is by definition the same as place of production, including various forms of private and public service, for example, hairdressing and hospitals. For immobile commodities, the relation between demand and supply of commodities is direct as there is no interregional trade and, therefore, there are no transport costs. In the case of hairdressing, the problem of transport costs is related to shopping trips. This is also the case for a number of components of consumption, for example, services related to real estate.

Second, different price concepts are used. Commercial margins and net commodity taxes enter into the full model and in relation to the transport commodity, which means that price depends on the level of net commodity taxes (for example, fuel taxation and road pricing).

Third, in a detailed version of LINE, the transport sector can be subdivided into different transport sub-sectors, each having different productivity and employment levels.

4. LINE: the Full Model, a Graphical Presentation

Here, a brief graphical presentation of LINE is made. The full model and its equations are described in detail in Madsen et al. (2001a). The data used in the model, together with the interregional SAM, are described in Madsen & Jensen-Butler (2002b) and Madsen et al. (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. Figure 3 shows the general model structure, based upon the real circuit employed in LINE. The horizontal dimension is spatial: place of work (denoted R), place of residence (T) and place of demand (S). Production activity is related to place of work. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of demand. The vertical dimension is more detailed and follows with its five-fold division the general structure of a SAM model. Production is related to activities; factor incomes are related to i) activities by sector; ii) factors of production with labour by sex, age and education; iii) institutions: households; iv) demand for commodities is related to wants (aggregates of commodities or components of final demand and intermediate consumption); v) commodities, irrespective of use.

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in figure 3. Starting in cell RE in the upper left corner, production generates factor incomes in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors (RE) to sex, age and educational groups (RG). Factor income is then transformed from place of production (RG) to place of residence (TG) through a commuting model. Employment follows the same path from sectors (RE) to sex, age and educational groups (RG) and further from place of production (RG) to place of residence (TG). Employment and unemployment are determined at place of residence (TG).

Disposable income is calculated in a sub-model where taxes are deducted and transfer and other incomes are added. Disposable income is distributed from factors (TG) to households (TH). This is the basis for determination of private consumption in market prices, by place of residence (TW). Private consumption is assigned to place of demand (SW) using a shopping model. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities (SV) in basic prices through a use matrix. In this transformation from market prices to basic prices (from SW to SV), commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production. Through a trade model, exports to other regions and production for the region itself are determined (from SV to RV). Adding export abroad, gross output by commodity is determined. Through a reverse make matrix, the cycle returns to production by sector (from RV to RE).

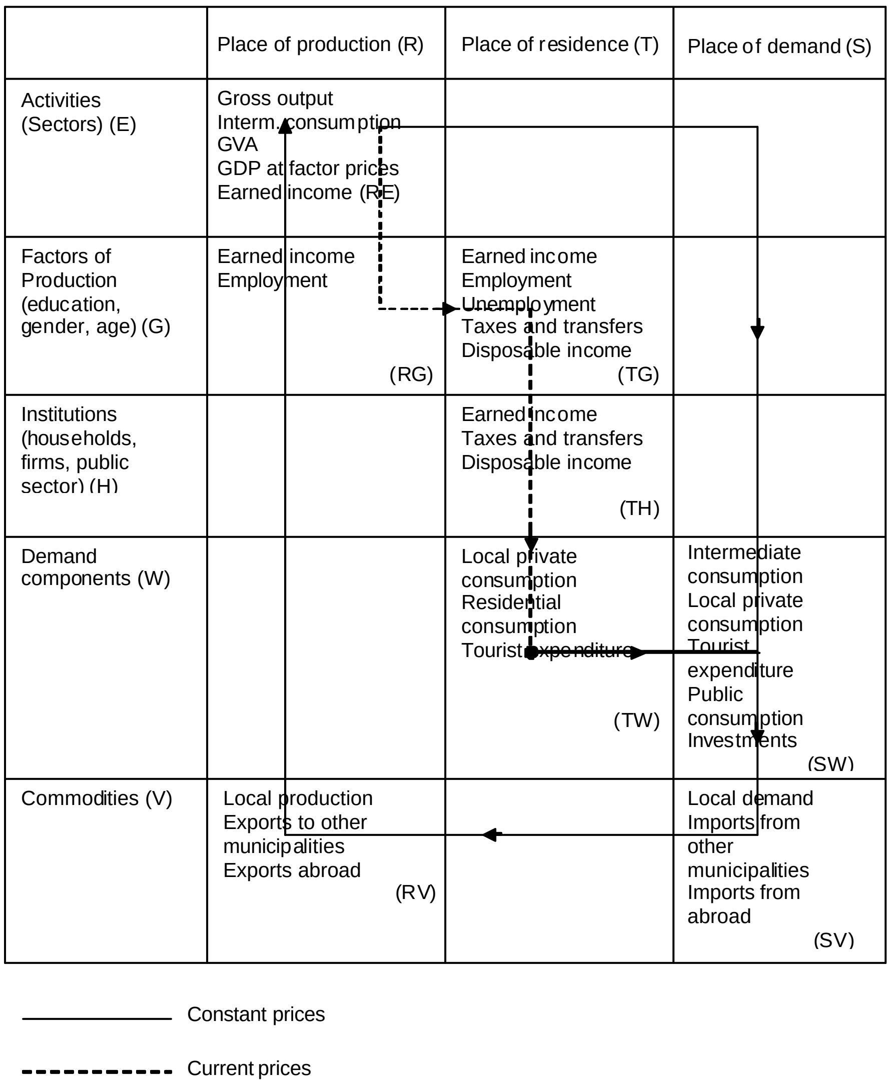

Figure 3. Simplified version of LINE: the real circuit

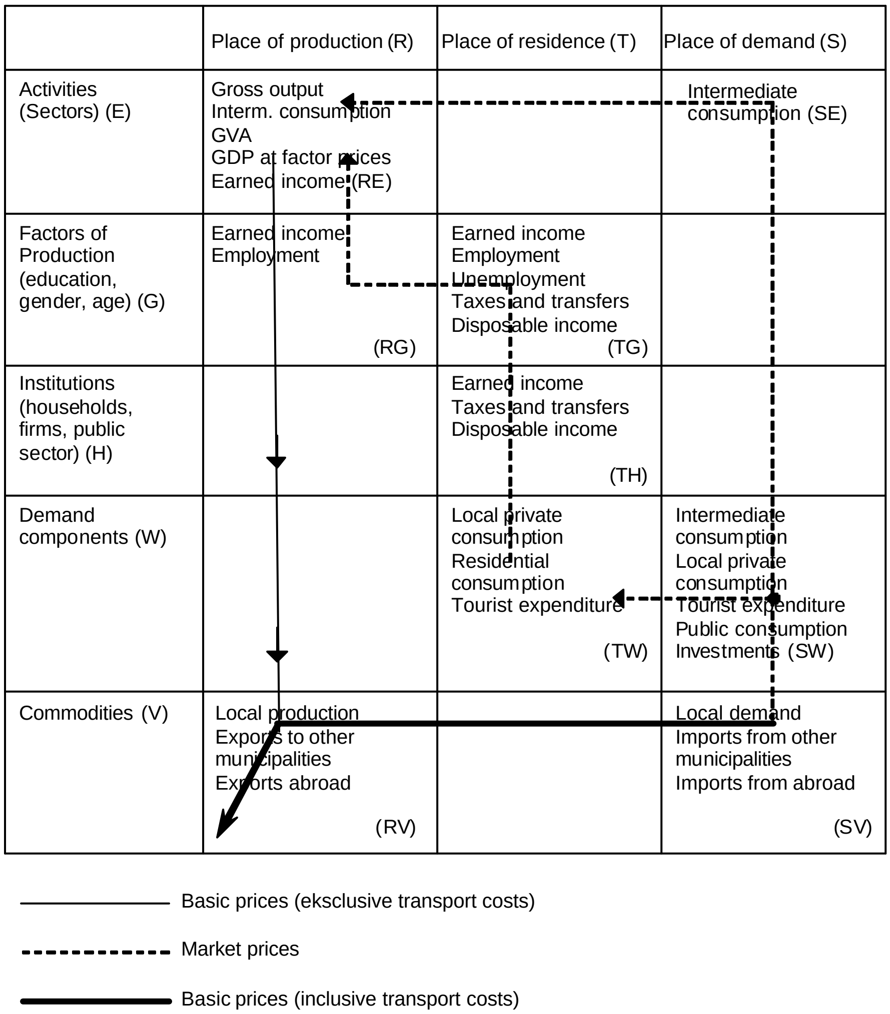

Figure 4. Simplified version of LINE: the cost-price circle

The stylised version of the model with the real circle illustrated, as well as the price concepts used, is shown in figure 3, where the price level of real circle variables (constant/current) is shown.

Again using the stylised version of the model shown in figure 3, the anticlockwise cost/price circuit shown in figure 4 corresponds to the dual problem. In cell RE, sector basic prices (current prices) are determined by costs (intermediate consumption, value added and indirect taxes, net in relation to production). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (from RE to RV). These are then transformed from place of production to place of demand (RV to SV) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes (from SV to SW). This transformation takes place using a reverse use matrix. Finally, private consumption is transformed from place of demand to place of residence in market prices (from SW to TW). Figure 3 shows the structure of LINE in more detail.

4.1. The Dimensions of LINE

In the standard version of LINE, the dimensions of the axes are normally the following:

Sectors: 12 sectors aggregated from the 133 sectors of the national accounts.

Factors: 7 age, 2 sex and 5 education groups.

Households: 4 types, based upon household composition.
Needs: For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.
Commodities: 20 commodities, aggregated from 131 commodities in the national accounts.
Regions: 277 municipalities (the lowest level of spatial disaggregation). Regions are defined either as place of production, place of residence or as place of demand. It is possible to aggregate the (277) municipalities into any regional unit. Standard regions are the (16) counties and (45) labour-market districts.

In the version of the model used here, 23 sectors are used, 27 commodities and an aggregation of factors and households has been made, so that they do not enter the model. It uses 16 counties (regions).

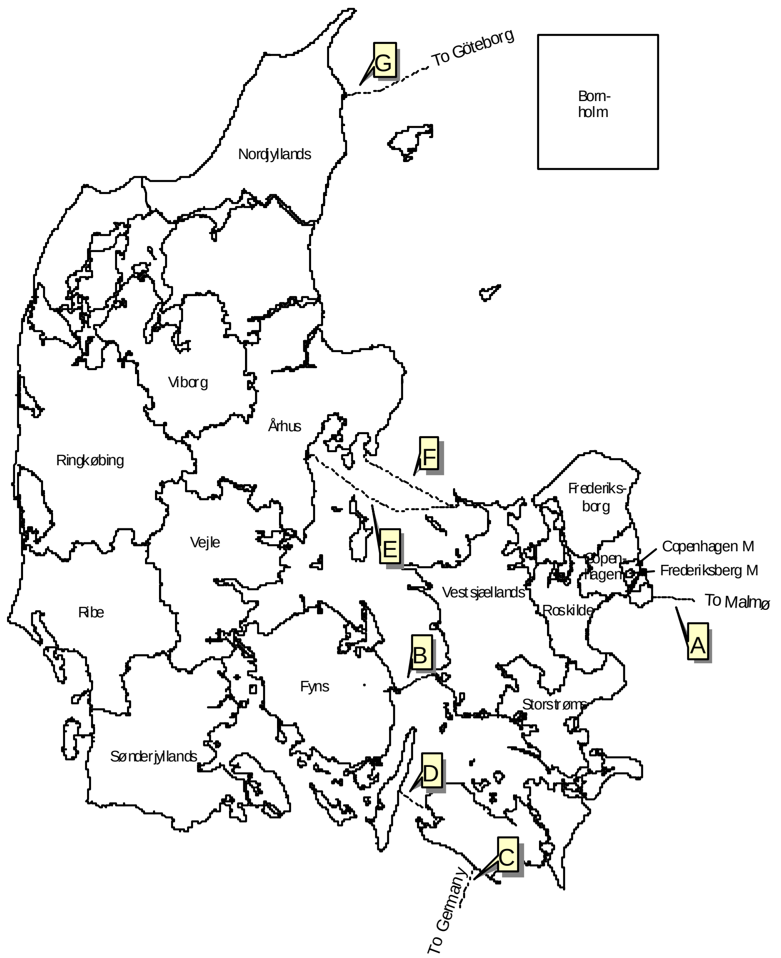

Figure 5. Danish regions (counties and two municipalities with county status, Copenhagen M and Frederiksberg M). Three fixed links: A: Oresund, to Malmo, Sweden, B: Great Belt, C: Femer Belt to Germany. Four ferry routes: D: Spodsbjerg-Taars, E: Odden-Aarhus (Mols Line), F: Odden-Ebeltoft (Mols Line), G: Frederikshavn-Gothenburg (Sweden). Other very local and international ferry routes are not shown

5. Road Pricing and Modelling its Impacts

The design of road pricing systems relates to general issues concerning transport policy and technical constraints and possibilities, in concrete social and cultural contexts.

5.1 Road Pricing

Five basic dimensions underlie all road pricing systems.

1) Whether the tariff is kilometre dependent, time dependent or flat rate
2) Whether the tariff depends on the type of road to be used (motorway, main road, secondary road, etc.)
3) Whether the tariff depends upon type of area in which the road is used (for example, urban, rural or simply the national territory)
4) Whether the tariff depends on time of day (rush hour, daytime, evening, night)
5) Whether the tariff depends upon behaviour (changes in speed, for example)

For example, an urban cordon is a flat-rate charge for entering a specific type of area (as in the case of London). A motorway toll is typically kilometre and road type dependent (as in the case of the proposed German motorway lorry charges). Choice of system depends partly upon the dimensions chosen and partly upon technological, administrative and political alternatives available.

In Denmark, a pilot project (AKTA, see Nielsen 2000, 2003 Herslund 2003, Herslund et al. 2001) is at present being developed involving both kilometre and area dependent tariffs. In the future, more complex systems, which also take account of the road hierarchy and time of day, may be developed. Technically, it is based on GPS technology, permitting precise identification of the location of the vehicle and thereby its road use related in turn to toll level for the road. This level depends on road status in a road hierarchy, time of day and level of urbanisation. Cars are fitted with receivers which function as meters registering both current expenditure as the road is used, and cumulated expenditure for a given period. The meter is red at periodic intervals and the user is charged.

6. Results from the Danish Road Pricing Toll Study

Application of LINE permits analysis of the consequences for the regional economy of any change in the transport system which affects the costs of transport. The change in transport costs examined in this case, the introduction of road pricing, has been described above.

The analysis begins in the interaction components of the cost-price circle shown in figure 4. Starting with trade in commodities (RV to SV), the prices of commodities decline. Given the point at which the analysis commences, the presentation follows the two circles, where first the effects on commodity prices are derived, followed by the real effects on demand, production, employment and income. For other cases, the starting point depends on the nature of the initial shock.

6.1. Changes in Transport Costs

Changes in transport costs are calculated using a) an interregional satellite account for transport used to determine *levels* of transport costs and b) exogenously given interregional transport costs, based on a digital road map**,** *Vejnet DK*, used to calculate *changes* in transport costs.

The data in the interregional satellite accounts are estimated in four steps:

a1) Taking the national make and use tables, national transport activity is determined by i) transport mode and ii) subdivided by transport costs related to intermediate consumption (by sector) and to private consumption (by component) and iii) by external (transport firm based) and internal (own transport, within a non-transport producing firm or a household) costs. Six different modes of transport activity are used in the interregional satellite accounts, four for passenger transport and two for goods. Passenger transport is divided into car, rail, aeroplane and other and freight is divided into lorry and rail.

a2) In the second step, national transport activity related to passenger transport is subdivided (using data from the National Travel Survey) by trip purpose: i) commuting, ii) shopping, iii) tourism, iv) business travel and v) recreation.

a3) National transport activity is then divided by origin and destination using data on intra and inter-regional trade (freight and business trip transport activity) and interregional shopping, tourism and commuting (personal trip transport activity).

a4) Regional transport activity is then corrected (using regionalised National Travel Survey data) to ensure that the data reflect regional transport activity by mode.

Changes in interregional transport activity for car transportation are estimated using the digital road map *Vejnet DK*. Transport costs in Vejnet DK are based upon both time and distance where the generalised cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. In addition, costs are calculated both with and without road pricing. The calculations are based on assumptions shown in Table 1.

Table 1. Maximum speeds, distance and time costs, road pricing tariffs (DKK) (DKK 7.50 = approx. 1 Euro = approx. 1$US)

	Car	Lorry
Motorway	110 km/h	80 km/h
Non-urban highway	80 km/h	70 km/h
Urban	50 km/h or local restrictions taken from VejnetDK	Max 50 km/h or local restrictions if under 50 km/h
Distance cost per kilometre	1.82 DKK	2.60 DKK
Time cost per hour	0.75	2.78 DKK.
Road pricing – urban	0.60	-
Road pricing – rural	0.30	-

The estimation of level of transport activity by region, mode, purpose and by type of consumption described above reflects a basic assumption that data on transport activity obtained from National (transport satellite) Accounts used in a top-down procedure are superior to data on transport activity obtained from different statistical sources used in a bottom-up approach.

In this paper, only results based upon road pricing for private cars are presented.

Table 2 shows the consequences of introducing road pricing. It is assumed that all ferry routes and fixed links will continue with unchanged ticket prices. The table shows that transport costs in general increase from 2% to 13%, outside the main cities of Copenhagen and Aarhus least in the interregional links where use of rural roads is important and/or where a significant part of the journey uses ferries. In Copenhagen and Aarhus, transport costs decline as road pricing results in a reduction of congestion, and thus, transport costs.

Table 2.

2.2. Changes in total transport costs (%) for transport between Danish regions after road pricing for cars

(%)	Cop. & Frb M	Cop C	FrC	RoC	VsC	SsC	BhC	FyC	SjC	RbC	VjC	RkC	ÅrC	ViC	NjC
Copenhagen & Frederiksberg M	0.91	0.96	1.02	1.01	1.06	1.07	1.00	1.05	1.07	1.07	1.07	1.05	1.01	1.04	1.04
Copenhagen C	0.96	1.13	1.13	1.13	1.13	1.12	1.00	1.08	1.09	1.09	1.09	1.05	1.02	1.05	1.05
Frederiksborg C	1.02	1.13	1.10	1.12	1.11	1.12	1.00	1.08	1.09	1.09	1.08	1.04	1.02	1.05	1.05
Roskilde C	1.01	1.13	1.12	1.08	1.13	1.11	1.00	1.07	1.09	1.09	1.08	1.09	1.02	1.05	1.05
Vestsjællands C	1.06	1.13	1.11	1.13	1.12	1.11	1.01	1.05	1.08	1.08	1.07	1.08	1.00	1.04	1.04
Storstrøms C	1.07	1.12	1.12	1.11	1.11	1.13	1.02	1.07	1.09	1.09	1.08	1.09	1.03	1.06	1.05
Bornholms C	1.00	1.00	1.00	1.00	1.01	1.02	1.09	1.02	1.03	1.03	1.03	1.03	1.01	1.02	1.02
Fyns C	1.05	1.08	1.08	1.07	1.05	1.07	1.02	1.12	1.12	1.12	1.12	1.12	1.10	1.11	1.12
Sønderjyllands C	1.07	1.09	1.09	1.09	1.08	1.09	1.03	1.12	1.15	1.12	1.12	1.11	1.10	1.11	1.12
Ribe C	1.07	1.09	1.09	1.09	1.08	1.09	1.03	1.12	1.12	1.12	1.12	1.11	1.10	1.11	1.11
Vejle C	1.07	1.09	1.08	1.08	1.07	1.08	1.03	1.12	1.12	1.12	1.12	1.11	1.07	1.11	1.11
Ringkøbing C	1.05	1.05	1.04	1.09	1.08	1.09	1.03	1.12	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Århus C	1.01	1.02	1.02	1.02	1.00	1.03	1.01	1.10	1.10	1.10	1.07	1.11	0.97	1.10	1.09
Viborg C	1.04	1.05	1.05	1.05	1.04	1.06	1.02	1.11	1.11	1.11	1.11	1.11	1.10	1.11	1.09
Nordjyllands C	1.04	1.05	1.05	1.05	1.04	1.05	1.02	1.12	1.12	1.11	1.11	1.11	1.09	1.09	1.12

6.2. Changes in Commodity Prices and Disposable Incomes

Table 3, column 1, shows that prices for commodities produced domestically at the national level increase by 0.10%. However, prices fall in Greater Copenhagen, whilst they increase with increasing distance away from Copenhagen, except for Bornholm, which benefits from transport via Copenhagen. Likewise, price increases in Aarhus, the other main urban centre are lower than elsewhere in the periphery.

Import prices (column 2) are not really affected by road pricing for imports on their way to the Danish market. This means that prices for the total demand (column 3) rise by a similar, though slightly smaller percentage and the regional distribution of price rises has the same pattern as for demand for domestic products.

Column 4 shows that prices for intermediate consumption are similarly affected by the reduction in transport costs, related to the fact that only service commodities enter into the calculations. These changes affect prices of gross output (column 5) though their effect is smaller as intermediate consumption is a part of the gross output.

Column 6 shows that export prices relative to foreign prices increase by 0.12%, again least in Greater Copenhagen and most in the industrial and peripheral regions of Jutland. The regional pattern is similar to that in column 1 and for the same reasons.

Column 7 shows private consumption by place of demand, and exhibits a similar structure to the previous columns in the table. However, when private consumption by place of residence is examined (column 8), significant changes appear because road pricing affects the cost of trips for shopping, trips to visit family and friends, cultural and recreational visits, as well as tourist trips. There are now substantial price increases in the outer areas of Greater Copenhagen and Aarhus. This is because of longer trips and higher road price tariffs.

Table 3.

Price changes for demand and supply by type, by geographical origin.
Percentage changes

	(1) Demand: domestic production (SV)	(2) Foreign import (RV)	(3) Demand (SV)	(4) Intermediate consumption (RE)	(5) Gross output (RE)	(6) Foreign export (RV)	(7) Private consumption Place of market place (SW)	(8) Private consumption Place of residence (TH)
Copenhagen & Fr. berg Municip.	-0.10	0.00	-0.08	-0.04	-0.07	0.13	-0.04	-0.17
Copenhagen County	-0.04	-0.01	-0.04	-0.02	0.00	0.39	-0.01	0.46
Frederiksborg County	0.12	-0.03	0.09	0.09	0.14	0.10	0.07	0.55
Roskilde County	0.09	-0.02	0.07	0.08	0.12	0.14	0.06	0.48
Vestsjællands County	0.18	-0.02	0.15	0.14	0.26	-0.01	0.11	0.64
Storstrøms County	0.21	-0.02	0.18	0.16	0.24	0.05	0.12	0.69
Bornholms County	0.04	-0.01	0.03	0.04	0.07	0.16	0.03	0.38
Fyns County	0.19	-0.02	0.16	0.15	0.23	0.08	0.12	0.65
Sønderjyllands County	0.24	-0.01	0.20	0.19	0.29	0.10	0.15	0.83
Ribe County	0.26	-0.02	0.21	0.20	0.34	-0.04	0.16	0.74
Vejle County	0.25	-0.02	0.20	0.19	0.32	0.03	0.14	0.74
Ringkøbing County	0.20	-0.02	0.16	0.15	0.29	-0.01	0.11	0.63
Aarhus County	0.08	0.00	0.07	0.08	0.12	0.16	0.05	-0.03
Viborg County	0.17	-0.01	0.14	0.13	0.23	0.11	0.10	0.59
Nordjyllands County	0.17	-0.01	0.14	0.13	0.22	0.11	0.11	0.62
Outside the regions	0.06	-0.01	0.04	0.05	0.07	0.01	-	-
Whole country	0.10	0.00	0.08	0.09	0.14	0.12	0.07	0.44

6.3. Changes in Demand, Production and Income

In general, road pricing means that real private consumption declines markedly, as consumer prices increase. On the other hand, export declines less because road pricing for cars only affects export prices marginally. Total demand and total production are therefore affected to a lesser degree than is the case for private consumption.

Table 4, column 1 shows the consequences for disposable income (in current prices) of increases in transport costs which affect commuting. As most commuting is towards Copenhagen, then the principal increases are to be found outside Copenhagen and Aarhus. The decrease in disposable income registered for Aarhus arises because transport costs in Aarhus decrease, as a result of reductions in congestion and the shorter commuting distances in Aarhus, as compared to Copenhagen.

Column 2 shows how real disposable income changes if price reductions on commodities are also included. The overall reduction in real disposable income is almost 1%. The effect is almost identical to that for private consumption by place of residence (column 3). Here again, Copenhagen and Frederiksberg Municipalities and Aarhus have small absolute gains, while all other regions have losses which become greater with increasing distance from Copenhagen. Column 4 shows the increase in private consumption by place of demand, reflecting the more even spread of the effects noted in column 3 through shopping trips. Column 5 shows the real effect on total demand, which is more than for private consumption. The impacts are negative for all regions, though these negative effects are lowest in the cities.

This pattern is the same for changes in real production, intermediate consumption and Gross Value Added (see columns 9 and 10).

Column 8 shows the effects on exports of both the price increases for exports noted in Table 4 and the regional commodity export composition, as different commodities have different price elasticities. Correspondingly, import from abroad is calculated as a function of changes in domestic prices, which rise, and import prices from abroad, which in general are unchanged (see column 6 in Table 4). LINE uses the national import and export price elasticities used in Statistics Denmark's national macro-economic model, ADAM (Dam 1995).

Table 4

Consequences for demand, production and income. Percentage changes.

	Disposable income (current prices) (TH)	Real disposable income (TH)	Private consumption Place of residence (TW)	Private consumption Place of demand (SW)	Demand (SV)	Foreign imports (SV)	Demand Domestic production (SV)	Foreign export (RV)	Gross output (RE)	GDP at factor prices (RG)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Copenhagen & Frederiksberg M	-0.05	0.17	0.17	-0.06	-0.05	-0.03	-0.05	-0.01	-0.08	-0.07
Copenenhagen C	-0.21	-0.71	-0.71	-0.68	-0.23	-0.17	-0.25	-0.15	-0.23	-0.25
Frederiksborg C	-0.28	-1.24	-1.24	-1.20	-0.54	-0.56	-0.52	-0.34	-0.48	-0.49
Roskilde C	-0.27	-1.03	-1.03	-0.99	-0.50	-0.50	-0.49	-0.35	-0.46	-0.47
Vestsjællands C	-0.26	-1.40	-1.40	-1.37	-0.64	-0.60	-0.65	-0.57	-0.66	-0.64
Storstrøms C	-0.27	-1.50	-1.51	-1.47	-0.70	-0.65	-0.70	-0.48	-0.66	-0.69
Bornholms C	-0.20	-0.95	-0.96	-0.97	-0.41	-0.36	-0.41	-0.18	-0.37	-0.41
Fyns C	-0.25	-1.41	-1.41	-1.40	-0.62	-0.55	-0.63	-0.43	-0.59	-0.61
Sønderjyllands C	-0.34	-2.02	-2.03	-1.98	-0.77	-0.61	-0.77	-0.45	-0.72	-0.75
Ribe C	-0.26	-1.56	-1.57	-1.56	-0.67	-0.54	-0.69	-0.60	-0.71	-0.67
Vejle C	-0.28	-1.43	-1.43	-1.41	-0.61	-0.50	-0.63	-0.59	-0.66	-0.61
Ringkøbing C	-0.25	-1.48	-1.49	-1.48	-0.59	-0.46	-0.62	-0.50	-0.63	-0.59
Aarhus C	0.01	0.05	0.05	-0.01	-0.08	-0.03	-0.10	-0.26	-0.17	-0.11
Viborg C	-0.27	-1.50	-1.51	-1.49	-0.59	-0.46	-0.61	-0.42	-0.58	-0.58
Nordjyllands C	-0.26	-1.41	-1.42	-1.39	-0.57	-0.46	-0.58	-0.39	-0.56	-0.56
Outside the regions	-	-	-	-	-0.04	-0.01	-0.05	0.00	-0.16	-0.13
Whole country	-0.20	-0.98	-0.98	-0.98	-0.41	-0.33	-0.42	-0.33	-0.41	-0.40

6.4. Changes in Employment and Income

Table 5 column 1 shows that employment declines by 9,764, (by place of production).

The distribution of these employment decreases closely follows the distribution of increases in Gross Output from Table 4. Fyn and North Jutland have the biggest declines in absolute terms whilst Greater Copenhagen and Aarhus have, in relative terms, the smallest declines. By place of residence, differences are somewhat reduced. Column 3 shows the consequences for earned income (wages and salaries plus surplus on self employment) that decrease markedly in the areas which suffer from higher commuting costs. These losses are modified by decreases in tax payments, (column 5) because of the income effect. Changes in transfer incomes (column 4) further modify the pattern of income change. Increases in transfer incomes are, other things being equal, greatest in the regions where employment declines faster.

Column 6 shows the net result of these changes on disposable income. Greater Copenhagen and Aarhus are almost neutral and declines are related to increasing distance from Copenhagen.

Table 5.

Impacts on employment and disposable income

	(1) Employment at place of production (RG)		(2) Employment at place of residence (TG)		(3) Earned Income (TG)	(4) Income transfers (TG)	(5) Taxes (TG)	(6) Disposable income (TG)
	Pct	Number	Pct	Number				
Copenhagen & Fr.berg M	-0.08	-291	-0.14	-434	-0.13	0.13	-0.09	-0.05
Copenhagen C	-0.21	-787	-0.19	-604	-0.39	0.18	-0.36	-0.21
Frederiksborg C	-0.41	-648	-0.32	-638	-0.52	0.39	-0.48	-0.28
Roskilde C	-0.39	-376	-0.30	-389	-0.48	0.43	-0.48	-0.27
Vestsjællands C	-0.52	-675	-0.46	-686	-0.57	0.39	-0.52	-0.26
Storstrøms C	-0.55	-598	-0.50	-623	-0.61	0.33	-0.54	-0.27
Bornholms C	-0.32	-64	-0.31	-63	-0.44	0.17	-0.41	-0.20
Fyns C	-0.50	-1125	-0.49	-1146	-0.56	0.33	-0.50	-0.25
Sønderjyllands C	-0.60	-755	-0.59	-753	-0.71	0.49	-0.65	-0.34
Ribe C	-0.56	-674	-0.55	-646	-0.58	0.55	-0.50	-0.26
Vejle C	-0.52	-954	-0.50	-916	-0.59	0.52	-0.53	-0.28
Ringkøbing C	-0.51	-757	-0.50	-735	-0.56	0.70	-0.48	-0.25
Aarhus C	-0.11	-347	-0.14	-449	-0.03	0.13	0.00	0.01
Viborg C	-0.47	-579	-0.46	-562	-0.57	0.46	-0.52	-0.27
Nordjyllands C	-0.46	-1134	-0.45	-1120	-0.56	0.39	-0.50	-0.26
Outside the regions	0.00	0	-	-	-			-
Whole country	-0.35	-9764	-0.35	-9764	-0.43	0.33	-0.38	-0.20

6.5. Recycling the Revenue from Road Pricing: a Balanced Budget

The revenue arising from road pricing can be used for different purposes. The allocation of these revenues by activity will have different economic effects as well as different effects in terms of regional distribution.

The following alternatives are examined:

1. Reduction of income tax: high rate taxation
2. Reduction of income tax: low rate taxation
3. Reduction of commodity taxes: VAT
4. Reduction of commodity taxes on fuel

Table 6a shows the consequences of reducing tax income by the state, whilst Table 6b shows the combined effects of road pricing and reductions in taxation.

Table 6a shows that disposable income for households increases most if income taxes are reduced and least if commodity taxes are reduced. This can be explained by the fact that reductions in commodity taxes in part are transferred abroad via exports and to other components of final demand.

There are regional differences in the different tax reduction strategies. Reduction of income taxes benefits Greater Copenhagen marginally more than the rest of the country. This is because the marginal tax rate in Greater Copenhagen lies above the national average because of the progression in the tax system. Alternatively, reduction of commodity taxes benefits the peripheral areas in Jutland because the marginal propensity to consume is higher in these areas. Regionally, reduction of income taxes at the lower bound provides the Greater Copenhagen area (except for the municipalities of Copenhagen and Frederiksberg) with a slightly greater increase in disposable income than reduction of upper bound taxes. This is probably related to higher levels of housing consumption, which in turn explains higher relative deductions from gross income, for tax purposes, as interest can only be deducted at the rate corresponding to the lower bound.

Table 6b shows the net effect of road pricing and tax recycling. The principal result is that combined road pricing and tax reduction give a small increase in disposable income. This can be explained by the fact that even though there is a balanced budget, the expenditure on road pricing by the individual household is tax deductible. The other result is that recycling via commodity taxes results in a decrease in disposable income. This can again be explained by the fact that reductions in commodity taxes do not benefit domestic private consumption to the full extent of the reduction, as discussed above.

Regionally, the net effects are similar to the gross effects because the regional differences in tax reductions are very limited.

Table 6a.

Consequences for demand, production and income. Effects arising from reductions in taxation, percentage changes.

	Real disposable income at place of residence (TG)				Employment at place of production (RG)			
	State income tax		Commodity taxes		State income tax		Commodity taxes	
	Lower bound (1)	Top bound (2)	General (3)	Transport commodity (4)	Lower bound (5)	Top bound (6)	General (7)	Transport commodity (8)
Copenhagen & Fr.berg M	1.19	1.14	0.67	0.67	0.30	0.29	0.17	0.19
Københavns C	1.25	1.17	0.67	0.67	0.34	0.33	0.17	0.23
Frederiksborg C	1.22	1.18	0.72	0.72	0.38	0.37	0.22	0.24
Roskilde C	1.18	1.17	0.72	0.72	0.43	0.43	0.21	0.27
Vestsjællands C	1.08	1.12	0.69	0.69	0.38	0.39	0.11	0.29
Storstrøms C	1.07	1.11	0.74	0.74	0.40	0.41	0.21	0.31
Bornholms C	1.03	1.09	0.74	0.74	0.35	0.36	0.02	0.34
Fyns C	1.09	1.12	0.69	0.69	0.36	0.37	0.14	0.29
Sønderjyllands C	1.06	1.08	0.75	0.75	0.31	0.32	0.16	0.35
Ribe C	1.07	1.09	0.70	0.70	0.33	0.34	0.04	0.32
Vejle C	1.09	1.11	0.72	0.72	0.33	0.34	0.08	0.29
Ringkøbing C	1.05	1.08	0.71	0.71	0.31	0.32	0.05	0.33
Aarhus C	1.13	1.14	0.74	0.74	0.36	0.37	0.17	0.28
Viborg C	1.06	1.10	0.74	0.74	0.32	0.33	0.08	0.32
Nordjyllands C	1.06	1.11	0.74	0.74	0.33	0.35	0.08	0.31
Outside the regions	-	-	-	-	0.00	0.00	0.00	0.00
Whole country	1.13	1.13	0.71	0.70	0.34	0.35	0.14	0.27

Table 6b.

. Consequences for demand, production and income. Net effects (gross effects minus effects arising from tax reductions), percentage changes

	Real disposable income at place of residence (TG)				Employment at place of production (RG)			
	State income tax		Commodity taxes		State income tax		Commodity taxes	
	Lower bound (1)	Top bound (2)	General (3)	Transport commodity (4)	Lower bound (5)	Top bound (6)	General (7)	Transport commodity (8)
Copenhagen & Fr.berg M	1.36	1.31	0.84	0.84	0.22	0.21	0.09	0.11
Københavns C	0.54	0.46	-0.05	-0.07	0.13	0.12	-0.04	0.02
Frederiksborg C	-0.02	-0.06	-0.52	-0.62	-0.03	-0.04	-0.19	-0.17
Roskilde C	0.15	0.14	-0.31	-0.38	0.04	0.04	-0.18	-0.11
Vestsjællands C	-0.32	-0.28	-0.71	-0.69	-0.14	-0.13	-0.41	-0.23
Storstrøms C	-0.44	-0.40	-0.76	-0.75	-0.15	-0.14	-0.34	-0.23
Bornholms C	0.08	0.14	-0.21	-0.13	0.03	0.05	-0.30	0.02
Fyns C	-0.33	-0.29	-0.72	-0.69	-0.14	-0.13	-0.36	-0.21
Sønderjyllands C	-0.96	-0.93	-1.26	-1.22	-0.29	-0.28	-0.45	-0.25
Ribe C	-0.49	-0.47	-0.86	-0.83	-0.23	-0.22	-0.52	-0.25
Vejle C	-0.33	-0.31	-0.71	-0.70	-0.18	-0.18	-0.44	-0.23
Ringkøbing C	-0.43	-0.40	-0.78	-0.74	-0.20	-0.19	-0.46	-0.18
Aarhus C	1.17	1.19	0.78	0.73	0.26	0.27	0.06	0.17
Viborg C	-0.44	-0.41	-0.76	-0.71	-0.15	-0.14	-0.40	-0.16
Nordjyllands C	-0.35	-0.30	-0.67	-0.64	-0.13	-0.11	-0.38	-0.15
Outside the regions	-	-	-	-	0.00	0.00	0.00	0.00
Whole country	0.15	0.15	-0.27	0.28	-0.01	-0.01	-0.22	-0.08

7. Limitations of the Model and Future Development Strategies

A central problem faced by input-output or more general demand-side approaches to regional economic analysis is the influence of supply-side conditions on production, this being a primary concern of CGE approaches. Another set of problems relates to some of the central concerns of contemporary urban and regional analysis: the existence of imperfect competition; externalities; product variety and growth in productivity all of which in a modelling context usually involve non-linear functional forms. In its present form, LINE builds on linear relationships. This raises the question of the suitability of LINE to deal with such issues.

In relation to the issue of supply-side conditions, as noted above, development of appropriate links between the real circle and the cost/price circle is the way forward. This road pricing study illustrates the first step, where links have been established between relevant prices and disposable income, foreign exports and imports. In addition, the public sector's budget and finance problems have been considered. A future strategy involves development of similar links for example, in relation to labour participation and productivity, or relating changes in commodity prices to the commodity composition of demand. Adjustments to changes in trade balances can also be included. The basis for this relation is the establishment of equilibrium in both commodity and factor markets and a steady-state equilibrium for institutional balances.

Even though this modelling strategy is similar to mainstream CGE approaches, the development of LINE nevertheless deviates from such CGE approaches to regional and interregional modelling. Both approaches are consistent with established economic theory and ensure equilibria with respect to markets and institutional balances. However, the mathematical complexity involved in the typical CGE approaches, which are often based upon non-linear functional forms, is attained at the expense of detail in the treatment of the regional and local economy. Thus, mainstream approaches, despite theoretical sophistication and complex non-linear mathematics, face severe problems related to lack of detail and a sound empirical foundation. They also frequently involve serious problems of calibration and solution.

One way of dealing with these reservations is to set up a model development strategy which involves the stepwise inclusion of behavioural components requiring non-linear functional forms. As described above, LINE can be developed in different ways. One important direction is a further development of the links between the real circle and the cost-price circle in order to model productivity, wage determination and labour force participation rates in the labour market and substitution and income effects in relation to commodity markets (private consumption, export etc.). Another important direction is to model in greater detail the consequences of a change in the institutional balances, for example, changes in household savings and consumption behaviour. These development strategies will transform LINE into a more advanced CGE model, as these essentially non-linear relationships are included in a step-by-step manner.

It might appear that the two modelling approaches converge towards a similar solution, this being an ideal CGE model. However, in reality the model development strategy employed in LINE, basically involving a linear system, represents a fundamentally different strategy to that utilised by mainstream CGE modelling, where there are often non-linearities in the central model equations which are solved simultaneously. This places substantial constraints on the number of different actors, markets and level of detail which can be incorporated in the models. In LINE, the complexity of the regional and sub-regional economic systems, including the possibility of choosing an appropriate model configuration, is in focus, whereas the mathematical complexity of selected behavioural components will be introduced in a gradual manner.

8. Conclusion

The requirements faced by model builders today are very diverse, determined by the great variety of problems faced by regions and local authorities and which are reflected in the variety of studies which they generate. The ideal modern modelling tool must be able to respond to this diversity of demands placed upon it. The aim of the construction of LINE described above is to ensure a high degree of flexibility, achieved in the basic structure which involves an interregional SAM. On this basis, it is possible to ensure flexibility in the following areas:

1. The model can be structured as either a sub-regional model, a regional model, or a combined model, as it includes both commodity markets and tourism, usually treated as regional phenomena, and labour markets, commuting and shopping which are typical sub-regional phenomena.
2. The overall model includes different types of agents which enter into a SAM, activities, factors, institutions, needs, commodities, which means that there is a degree of flexibility involving the option of including either all accounts or a choice of accounts, for example, a model covering activities or commodities (a local production environment model) or a model covering institutions and needs (an extended shopping model).
3. Use of three basic types of location. Place of production, place of residence and place of demand enter into the overall model. Choice of combination of type of locality permits the addressing of specific problems, such as a commuting model involving place of production and place of residence and a trade model involving place of production and place of demand.
4. The overall model involves a real circle and a cost-price circle. This permits development of a fixed price model by using the real circle alone or a general equilibrium model based upon links between the real circle and the cost-price circle.

Furthermore, given the above-mentioned more strategic modelling choices, even more flexibility can be introduced by choice of aggregation of categories of activities, factors, institutions etc.

The paper describes LINE and its use in a number of studies. The configuration of the model and the aggregation of the SAM accounts used in the analysis of the regional economic effects of road pricing are presented together with a summary of empirical results from the analysis. The magnitudes and directions of change are all satisfactory and theoretically defensible. The modelling system set up and demonstrated on an application case concerning the introduction of road pricing may also be relevant for other cases. Thus, it may be highly relevant to model the consequences of large new transport infrastructure. Here, it would be of major interest to address regional economic effects together with other effects relating to changes in transport efficiency and quality. The latter are normally the main focus of such studies, but planners and decision-makers could also benefit from the new possibilities in modelling set out with the suggested systems approach in this type of examination.

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Main Section C:

Regional Data and the General Interregional Social Accounting Matrix

Section 9:

Spatial Accounting Methods and the Construction of Spatial Social Accounting Matrices

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Spatial Accounting Methods and the Construction of Spatial Social Accounting Matrices

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ABSTRACT *The paper examines modifications to Regional Accounts used to construct regional and interregional Social Accounting Matrices (SAMs). It is argued that as the size of the basic areal unit used in studies declines, more traditional accounting approaches are no longer satisfactory. A three-dimensional spatial approach (termed two-by-two-by-two) to the identification of fundamental dimensions (commodity and factor market; geographical; and social accounts) has been developed in contrast to the more traditional non-spatial approach (termed two-by-two). This involves a novel approach using the geographical concepts of place of production for production activities, place of residence for institutions, marketplace for commodities and marketplace for factors. The use of these concepts permits accounting balances to be calculated at the spatial level. The theoretical basis of the spatial regional accounting model is presented and an example of the construction of a Danish Interregional SAM (SAM-K) is examined. Particular attention is given to data requirements, showing that these are much more modest than generally assumed.*

KEY WORDS: Interregional SAM, spatial accounting, data requirements

1. Introduction

Developments in spatial accounting and modelling have in part at least, been driven by policy-makers' growing interest in regional and local economic performance and interactions with other regions and localities.[1] This has promoted increased interest in development of regional information systems, where the national accounts-based systems are of considerable importance. These systems include Regional Accounts (Eurostat, 1996: Chapter 13), regional versions of satellite accounts (United Nations, 1993: Chapter XXI) and interregional versions of Social Accounting Matrices (SAM) (United Nations, 1993: Chapter XX; Hewings and Madden, 1995; Round, 1995, 2003; Thorbecke, 1998). The aim of this paper is to examine the necessary adaptations to Regional Accounts in

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order to construct such extended national account based regional information systems. This includes a novel systematic approach to the treatment of geographical structures and relations. The paper also provides an example of the implementation of these adaptations in the case of Denmark.

In National Accounts, a *two-by-two* registration of economic activities is usually employed, using the basic division between supply and demand on one dimension and type of commodity and type of factor on the other, with the nation and Rest of the World as the geographical units (United Nations, 1993; Eurostat, 1996). If these production accounts are divided by industry, an input–output table can be constructed (United Nations, 1993: Chapter XV; Eurostat, 1996: Chapter 9). If there is a further division by type of institution, a Social Accounting Matrix (SAM) can be derived (United Nations, 1993: Chapter XX). These accounts are inherently non-spatial, although this is usually of little consequence, as the division between the nation and the Rest of the World is present, and economic dependence on activities in the Rest of the World is usually relatively limited as is the need for information about spatial structure in relation to the Rest of the World.

In Regional Accounts (Eurostat, 1996: Chapter 13), the basic geographical unit is the region rather than the nation and they have a structure which is similar to National Accounts, although more simple. A number of differences can be noted. First, the focus of interest is the supply side, where there is no regional supply and demand balance, although the sum of regional supply is consistent with national totals. Second, there is no division by commodity and factor. Third, Regional Accounts are limited to recording production activities by industry and account for some institutional sectors such as households. Regional Accounts are also non-spatial, though this now becomes a problem as external links are much more important. This means that two major extensions are necessary if interregional accounting is to be possible. The first extension is to construct commodity balances and factor balances at the regional level. Whilst this is non-spatial, it gives the Regional Accounts the same two-by-two structure as the National Accounts. The second extension is to create the spatial dimension, extending the commodity and factor balances to include origin (supply) and destination (demand). This in essence creates a *two-by-two-by-two* structure. Finally, the term regional is inappropriate as a number of questions (commuting and shopping for example) can only be properly dealt with at the sub-regional or local spatial level. In the following, the analysis is as relevant for the local as for the regional level. Therefore, it is perhaps more appropriate to use the term local rather than Regional Accounts.

In interregional Social Accounting Matrices, a spatial registration of activities can be made. Spatial registration implies that activities are registered by place of origin of inputs and by destination of the outputs. Whilst the step of creating spatial balances is a natural extension of the principles used in National Accounts to include the spatial dimension, in the following this spatial registration is based upon the new and systematic use of the concepts of (i) place of production for production activities where the activity takes place, (ii) place of residence for institutions, (iii) marketplace for commodities, and (iv) marketplace for factors.

In this paper, the methods used to set up an interregional SAM for Denmark are presented, developing ideas found in Madsen and Jensen-Butler (1999, 2002). Based upon the application of spatial registration of activities the procedure is examined including the use of the commodity and factor marketplaces. It is also shown that an interregional Social Accounting Matrix can be set up for countries with limited data availability.

2. National and Regional Accounts

Regional Accounts are based upon the concepts and accounting principles used in National Accounts (United Nations, 1993: Chapter XIX; Eurostat, 1996: Chapter 13). However, for a number of reasons, the national accounting framework is inadequate for the registration of economic activities in small areas, where economic interaction between different areas is often intense and the degree of geographical specialisation is substantial. The national accounting framework is better suited to analyses based upon well-defined, coincident and relatively closed functional regions.

2.1. National Accounts and the Nation

The conceptual basis of the National Accounts is supply and use, subdivided by commodity. The mirror image of this concept is the institutional accounts, which are based upon ownership of the production of the nation, subdivided by type of institution. This gives a two-by-two structure, with supply and demand on the one dimension and commodities and factors on the other. The supply of commodities comes either from domestic production or from imports from abroad, and commodities are produced either by domestic or by foreign institutions. Demand for commodities is either domestic demand or foreign exports, and commodities are demanded either by domestic or foreign institutions. Domestic institutions are, on the one hand, either households or government, which generate final consumption, and on the other hand, production units which generate intermediate consumption, gross capital formation and changes in inventories.

Seen from both the demand and the production side, the geographical units used in National Accounts are the nation itself and the Rest of the World. A series of rules have been established to determine whether or not an institution belongs to the nation, in other words, what is the place of production of the institutional production unit and the place of residence of the demanding unit.

Using a terminology that is relevant in relation to Regional Accounts, the place of residence of institutions and, from a production point of view, the place of production of the institutions, are key concepts used here, which are derived from National Accounts. The National Accounts are one-dimensional, which means that an institution has one and only one geographical relation, this being whether the institution is resident or non-resident.

2.2. National Accounts and Geography

Normally, the concepts of place of residence and place of production are not used in National Accounts. However, in the context of regional economies they become important. The smaller the geographical scale, the more necessary it becomes to use the two concepts, as well as to introduce two new concepts, *marketplace for commodities* and *marketplace for factors*. The reason for this multi-dimensionality is that regions become more specialized as the areal unit for production, place of residence or marketplaces for commodities and factors becomes geographically smaller. As the size of areal unit declines, fewer and fewer regions retain all of their functions on all four dimensions.

In National Accounts, this problem also exists, but on a more limited scale. A nation normally includes all four functions, being place of production, place of residence and marketplaces for commodities and factors. The transformation from place of production to place of residence is included in the double entry spatial accounting and is financed through the balance of payments: incomes from production activities abroad and from foreigners working inside the national territory (international commuting) are added to residential institutional incomes. Also, other incomes from abroad and paid abroad are included in the transformation from place of production to place of residence. This is not done in conventional National Accounts, where it is only included as a correction in national disposable income.

The transformation from marketplace for commodities to place of residence is included in the determination of demand by domestic institution, by subtracting foreign tourists' demand from total demand. Again, this is a deviation from the single entry principle, undertaken in order to estimate residential private consumption. Tourists' demand is included as part of exports, because it constitutes foreign demand inside the nation (see Eurostat, 1996: Chapter 3.142). Foreign tourism can be business tourism (treated as part of intermediate consumption), private tourism (treated as part of private consumption) and governmental tourism (treated as part of governmental consumption). Tourism is transformed into exports in two steps. First, the different types of consumption including tourism are accounted for. In this step the marketplace for commodities is the area in question. In the second step, tourists' demand is subtracted from total demand and is added to exports as one commodity. The demand that remains is, therefore, residential demand. Similarly, tourists' consumption abroad, being a separate commodity in private consumption, is subtracted from demand by type of commodity and added to imports from abroad. In this way, commodity balances in the first step are accounted for using the marketplace for commodities, and in the second step they are transferred to the foreign trade balance by adding domestic tourism abroad to foreign imports and adding residents' tourism to foreign exports. Although these problems are managed in the National Accounts, from the point of view of Regional Accounts this solution is not satisfactory. Here, an application of all four geographical concepts is necessary.

The introduction of the concept of *marketplace for commodities* and *marketplace for factors* changes and supplements the methods used to set up regional Social Accounting Matrices. Estimation of production by place of production and income by place of residence follows the guidelines set up by the European Union (Eurostat, 1996). However, estimation of demand in the marketplace for commodities, interaction between place of production and marketplace for commodities (intra- and interregional trade) and interaction between place of residence and marketplace for commodities (local private consumption and domestic tourism) extend the methods used in setting up regional Social Accounting Matrices. In addition, estimation of demand for production factors in the marketplace for production factors, including the transformation of demand for production factors from place of production to place of factor markets, and transformation of supply of production factors from place of residence to place of factor markets extend the methods used in setting up SAMs. This means that the *two-by-two* basic structure is extended to become *two-by-two-by-two*, including the origins (supply of commodities and factors of production) and destinations (demand for commodities and factors of production). In the following, this spatial extension of the non-spatial framework is presented.

2.3. Regional Accounts and Spatial Registration of Economic Activities

In factor markets, supply and demand for production factors are to be found. Demand for production factors is determined by production at the place of production. In Figure 1, factor demand by sector is transformed into factor demand by type of production factor. On the supply side, supply of production factors by type of institution is transformed into supply by type of production factor. Supply of a production factor is related to the place of residence of the institution. The factor market is assigned geographically to the marketplace for factors.

In the case of labour, demand by sector can be transformed into demand by labour group defined using age, gender and education. Supply of labour is transformed from households

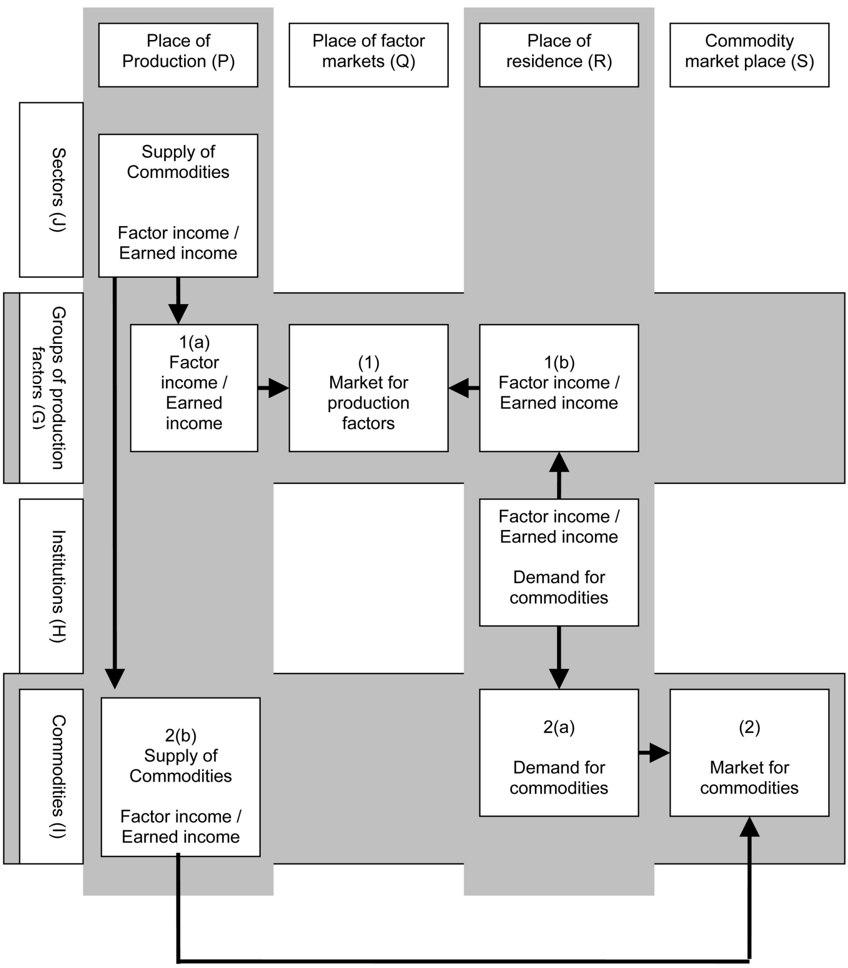

Figure 1. The conceptual basis of spatial social accounts

(institutions) to factor groups (such as age, gender and education). Geographically, the labour market links the place of production and the place of residence. In the real world, there are only a few examples of a pure spatially defined labour market, where the factor marketplace is separated from both the place of production and the place of residence. An example is the case where workers meet in the morning at a given location, where the employers hire manpower, and after negotiation, the workers are transported to the place of production. Normally, the link between place of production and place of residence is direct in a one-to-one relationship. From this point of view it cannot be determined whether the place of production or the place of residence is the labour marketplace. However, as the unemployed can be treated as an excess supply of labour, and unemployment by definition is only assigned to a place of residence, the labour market can be related to place of residence.

In the commodity market, there is a distinction between place of residence, the marketplace for commodities and place of production. The marketplace for commodities links the demand for the commodity (from the place of residence to the marketplace for commodities) to the supply of the commodity (from place of production to the marketplace for commodities). Before the transformation to the marketplace for commodities, the demand for commodities is transformed from income by institutional group to demand by commodity. On the supply side, production by sector is transformed from production by sector into production by commodity and then supply is related geographically to the marketplace for commodities.

2.4. Statistical Sources

One initial objection to this structure is its complexity. Requirements of simplicity have been behind development of the one-dimensional system. However, considering both data quality and existing data sources, it seems that this objection is no longer valid. By way of illustration, we show that data for two SAM elements (persons and commodities) are sufficient to establish the Regional Accounts.

First, by asking individuals, data on the supply side of the labour market (employment and earned income) can be obtained, as shown in block 1b in Figure 1. By asking firms or individuals, data on the demand side of the labour market (employment and earned income) can be obtained, as shown in block 1a. Second, by obtaining information on commodities from firms, data on the supply side of the commodity market (turnover) can be obtained, as shown in block 2b. Data on the demand side (turnover), can be obtained from individuals in the case of final consumption and from firms in the case of intermediate consumption, as shown in block 2a.

Individuals provide a good source of data, which with respect to block 1 are obtainable from a census. It is also possible that demand for factors (block 1a) can be obtained from surveys of firms. With respect to block 2, information is only exceptionally related directly to commodities, which would make it possible to obtain data. Instead, data have to be gathered either at the place of origin of the commodity (from producers at the place of production), at the marketplace for commodities (from retailers and wholesalers), or at the destination of commodities (from purchasers at the place of residence).

This simple model constitutes a good description of the statistical sources for the Regional Accounts – and shows why different transformations must be undertaken before the data can be used in the Regional Accounts. On the supply side, the production account in the Regional Accounts is based upon information from the place of production. Production statistics will have the format of Make (sector by product) matrices. Statistics on the labour force, employment and unemployment by type of labour and by type of household are often based upon census data, sometimes supplemented by other relevant population data. Finally, demand is, in many cases, most effectively determined at the place of commodity demand. For example, estimation of private consumption by commodity is often based upon VAT statistics, which is related to the marketplace for commodities.

Before using these statistics in the Regional Accounts, a number of corrections must be made. In the production statistics, the share of factor income received by non-residential institutions must be subtracted in order to obtain factor income by place of residence, which is the key concept in the Regional Accounts. In the demand statistics, demand from non-residential actors should be subtracted in order to obtain residential demand for locally produced commodities.

3. Interaction and Regional Accounts

The concept of a balance is fundamental for data construction and accounting. In this section, the accounting model behind the concept of the commodity balance and the institutional balance is examined in its most general form. The model, with a few modifications, is applicable to both regional and national levels. The basic model is transformed into a *two-by-two-by-two* spatial model by incorporating the concepts of *place of production*, *place of residence, place of commodity market* and *place of the factor market.* This process also represents a transition from a commodity trade balance to an institutional balance, involving balance of payments and the concept of place of residence.

The accounting balances in a *two-by-two* non-spatial regional accounting framework are first presented. This is followed by a discussion of modifications of the general model with a subdivision into separate balances, these being the private sector balances and the governmental balances, which corresponds to the balance of payments for the region. The savings balances can be subdivided into sub-balances, all related to the place of residence. A discussion of price concepts in the two balances is included later. Finally, extension to the *two-by-two-by-two* registration of activities, where sub-balances are made interregional, is presented and a subdivision of the different balances into balances for mobile and non-mobile commodities or components of demand is examined.

3.1. A Non-spatial Regional Accounting Model (Two-by-Two Model)

The point of departure for local commodity balances is, on the one hand, data on local supply (production) and local demand (intermediate consumption, private consumption, governmental consumption, investments) and on the other hand, the national commodity balances as represented in the national Make and Use tables. The difference in relation to the national commodity balance is that interregional imports and exports enter.[2] The core of the regional commodity balance in a SAM is the commodity balance equation for each region and each commodity, or the total balance:

$$\mathbf{q}_i^P + \mathbf{z}_i^{S,O} + \mathbf{z}_i^{S,F} = \mathbf{u}_{i,IC}^S + \mathbf{u}_{i,CP}^S + \mathbf{u}_{i,CO}^S + \mathbf{u}_{i,IN}^S + \mathbf{z}_i^{P,O} + \mathbf{z}_i^{P,F} \tag{1}$$

where $\mathbf{q}_i^P$ is the gross output by commodity i by place of production P; $\mathbf{z}_i^{S,O}$ is the interregional import (O) by commodity by place of commodity market S; $\mathbf{z}_i^{S,F}$ is the import from abroad (F) by commodity by place of commodity market; $\mathbf{u}_{i,IC}^S$ is the intermediate consumption (IC) by commodity by place of commodity market; $\mathbf{u}_{i,CP}^S$ is the private consumption (CP) by commodity by place of commodity market; $\mathbf{u}_{i,CO}^S$ is the governmental consumption (CO) by commodity by place of commodity market; $\mathbf{u}_{i,IN}^S$ is the local investment (IN) by commodity by place of commodity market; $\mathbf{z}_i^{P,O}$ is the interregional export by commodity by place of production; and $\mathbf{z}_i^{P,F}$ is the foreign export by commodity by place of production.

Equation (1) is formulated explicitly in geographical terms (using P and S). In this case there is no difference between the national and the regional perspective except that interregional trade has been introduced. From this commodity balance a progression is made to arrive at a set of institutional balances, corresponding to a process whereby the geographical dimension is transformed from place of production and commodity marketplace, to place of residence for regional institutions. This process starts by transforming the perspective on production so that it is seen from an institutional place of residence point of view, as shown in the following equation.

$$\begin{aligned}
&\mathbf{x}^P - \mathbf{u}_{IC}^S + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) \\
&\quad = \mathbf{u}_{CP}^S + \mathbf{u}_{CO}^S + \mathbf{u}_{IN}^S + (\mathbf{z}^{P,O} - \mathbf{z}^{S,O}) + (\mathbf{z}^{P,F} - \mathbf{z}^{S,F}) \\
&\qquad + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) \qquad (2)
\end{aligned}$$

where $\mathbf{x}^P$ is gross output by place of production (P); $\mathbf{u}_{IC}^{S,F}$, $\mathbf{u}_{IC}^{P,F}$, $\mathbf{u}_{IC}^{S,O}$, $\mathbf{u}_{IC}^{P,O}$ indicate intermediate consumption by foreign (F) or domestic firms (O) in the commodity marketplace (S) or by place of production (P); $\mathbf{h}^{R,F}$, $\mathbf{h}^{P,F}$, $\mathbf{h}^{R,O}$, $\mathbf{h}^{P,O}$ give Gross Value Added (GVA) by foreign production factors (F) or domestic production factors (O) in place of residence (R) or by place of production (P).

In equation (2), supply by place of production is transformed into GVA, by place of residence. This involves a number of steps. First, intermediate consumption is subtracted both on the supply and use sides of equation (1). Second, correction is made for the purchase of intermediate goods obtained from extra-regional suppliers and the purchase of intermediate goods in the region by extra-regional producers. Third, a correction is made for commuting, involving GVA that is generated by institutions resident outside the region and GVA that is brought into the region by institutions resident in the region but who are a factor of production that is employed outside the region. *Outside the region* is further differentiated into a foreign component and a domestic component. The result is that the left-hand side becomes the resident institutions' net earnings. This left-hand side is a first step towards constructing resident institutions' saving balances.

These factor payments from outside the region involve both labour and capital income. In equation (2), impacts on income or savings from net interest payments from outside the region should, in principle, also be included, but here they have been left out for reasons of simplification. Net interest payments could also be subdivided into domestic and foreign payments. On the right-hand side of the equation (2) the first steps in the transformation from a trade balance to a balance of payments are taken. This involves correction of the trade balance using net purchase of intermediate goods and corrections for commuting.

In the next step, gross savings are derived from gross earnings by subtracting private consumption for households resident in the region. This involves a correction for the private consumption in the region of households resident outside the region, and for private consumption outside the region of resident households. Again, outside the region is further differentiated into a foreign and a domestic component. Consequently, there is a further correction of the trade balance using net purchase for private consumption. This yields

$$\begin{aligned}
&\mathbf{x}^{P} - \mathbf{u}_{IC}^{S} + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) \\
&\quad + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) - \mathbf{u}_{CP}^{S} + (\mathbf{u}_{CP}^{S,F} - \mathbf{u}_{CP}^{R,F}) + (\mathbf{u}_{CP}^{S,O} - \mathbf{u}_{CP}^{R,O}) \\
&= \mathbf{u}_{CO}^{S} + \mathbf{u}_{IN}^{S} + (\mathbf{z}^{P,O} - \mathbf{z}^{S,O}) + (\mathbf{z}^{P,F} - \mathbf{z}^{S,F}) + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) \\
&\quad + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) + (\mathbf{u}_{CP}^{S,F} - \mathbf{u}_{CP}^{R,F}) + (\mathbf{u}_{CP}^{S,O} - \mathbf{u}_{CP}^{R,O}) \qquad (3)
\end{aligned}$$

where $\mathbf{u}_{CP}^{S,F}$, $\mathbf{u}_{CP}^{R,F}$, $\mathbf{u}_{CP}^{S,O}$, $\mathbf{u}_{CP}^{R,O}$ indicate private consumption by foreign private households (F) or domestic private households (O) in the commodity marketplace (S) or by place of residence (R).

In the fourth step, regional disposable income is derived by subtracting governmental consumption. In this process, account is taken of the fact that some governmental consumption takes place outside the region and that some governmental consumption inside the region has its origins in demand from institutions that are resident outside the region. Again, there is a correction of the trade balance using net consumption of governmental goods and services. This gives

$$\begin{aligned}
&\mathbf{x}^{P} - \mathbf{u}_{IC}^{S} + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) \\
&\quad - \mathbf{u}_{CP}^{S} + (\mathbf{u}_{CP}^{S,F} - \mathbf{u}_{CP}^{R,F}) + (\mathbf{u}_{CP}^{S,O} - \mathbf{u}_{CP}^{R,O}) - \mathbf{u}_{CO}^{S} \\
&\quad + (\mathbf{u}_{CO}^{S,F} - \mathbf{u}_{CO}^{R,F}) + (\mathbf{u}_{CO}^{S,O} - \mathbf{u}_{CO}^{R,O}) \\
&= \mathbf{u}_{IN}^{S} + (\mathbf{z}^{P,O} - \mathbf{z}^{S,O}) + (\mathbf{z}^{P,F} - \mathbf{z}^{S,F}) + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) \\
&\quad + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) \\
&\quad + (\mathbf{u}_{CP}^{S,F} - \mathbf{u}_{CP}^{R,F}) + (\mathbf{u}_{CP}^{S,O} - \mathbf{u}_{CP}^{R,O}) + (\mathbf{u}_{CO}^{S,F} - \mathbf{u}_{CO}^{R,F}) + (\mathbf{u}_{CO}^{S,O} - \mathbf{u}_{CO}^{R,O}) \qquad (4)
\end{aligned}$$

where: $\mathbf{u}_{CO}^{S,F}$, $\mathbf{u}_{CO}^{R,F}$, $\mathbf{u}_{CO}^{S,O}$, $\mathbf{u}_{CO}^{R,O}$ indicate government consumption by foreign governments (F) or domestic governments (O) in the commodity marketplace (S) or by place of residence of the government (R).

Finally, the institutional balance has been subdivided into a private and a governmental savings balance. This is for the sake of illustration only, in order to indicate the possibility of additional subdivisions of the savings balance in relation to different types of institution.

This yields

$$
\begin{aligned}
&[\mathbf{x}^P - \mathbf{u}_{IC}^P + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) - \mathbf{u}_{CP}^R - s^R + t^R] + [s^R - t^R - \mathbf{u}_{CO}^R] \\
&\quad = \mathbf{u}_{IN}^S + (\mathbf{z}^{P,O} - \mathbf{z}^{S,O}) + (\mathbf{z}^{P,F} - \mathbf{z}^{S,F}) + (\mathbf{u}_{IC}^{S,F} - \mathbf{u}_{IC}^{P,F}) + (\mathbf{u}_{IC}^{S,O} - \mathbf{u}_{IC}^{P,O}) \\
&\qquad + (\mathbf{h}^{R,F} - \mathbf{h}^{P,F}) + (\mathbf{h}^{R,O} - \mathbf{h}^{P,O}) + (\mathbf{u}_{CP}^{S,F} - \mathbf{u}_{CP}^{R,F}) + (\mathbf{u}_{CP}^{S,O} - \mathbf{u}_{CP}^{R,O}) \\
&\qquad + (\mathbf{u}_{CO}^{S,F} - \mathbf{u}_{CO}^{R,F}) + (\mathbf{u}_{CO}^{S,O} - \mathbf{u}_{CO}^{R,O})
\end{aligned} \tag{5}
$$

where: $\mathbf{s}^R$ gives the taxes by place of residence (R), and $\mathbf{t}^R$ the income transfers by place of residence.

Whilst at the international level there can be positive or negative residuals in the balances, this is not the case for the interregional components of the balances. As an example, the difference in relation to the national commodity balance is that interregional imports and exports enter, the sum of each being by definition equal. In the construction of the local commodity balance, the national commodity balance is used. The sum of each component over all regions is equal to the component at the national level. For each commodity, the sum of interregional imports equals the sum of interregional exports.

To summarize, the transformation from place of production to place of residence, gives regional net savings. The transformation from place of commodity market to place of residence gives regional net investment plus the balance of payments. This involves the following central corrections. The first correction is a conventional correction for interregional and foreign trade, where in relation to income, supply from domestic producers is isolated.

The second correction involves intermediate consumption: a part of intermediate consumption does not originate from production units producing in the region. For example, business tourism expenditure included in intermediate consumption by place of commodity market stems from production units located outside the region. Therefore, the net surplus on business tourist expenditure is added to both the right and left sides of the equation, as a reduction in business tourist expenditure for the resident production units and as an increase in the balance of payments for the tourist region.

The third correction is to private consumption. If consumption in central regions (with and above average number of retail centres) is included in residential consumption, private consumption is overestimated. Therefore, private residential consumption is reduced by the consumption from non-residents and residential private consumption in other regions is subtracted when calculating private saving. Similarly, expenditure on domestic tourism by non-residents is subtracted, and domestic tourist expenditure from residents outside the region is added. Both corrections on the left-hand side of equation (4) are added to the balance of payments on the right-hand side of the equation in order to maintain the accounting identity.

The fourth correction is for governmental consumption: governmental consumption with the region as place of commodity market for a government residing outside the region is subtracted, and governmental consumption of the region itself in other regions is added. Again a correction to the balance of payments on the right-hand side is added.

The fifth correction is for commuting: income losses from inward commuters are subtracted and income gains from outward commuters are added.

After these corrections, the savings account refers uniquely to the place of residence of the private and governmental institutions. For each of the corrections the identity between demand and supply at the national level holds. That is,

$$\mathbf{i}^P\mathbf{z}^{P,O} = i^S\mathbf{z}^{S,O}; \qquad i^R\mathbf{h}^{R,O} = i^P\mathbf{h}^{P,O}; \qquad i^S\mathbf{u}_{IC}^{S,O} = i^P\mathbf{u}_{IC}^{P,O};$$
$$\mathbf{i}^S\mathbf{u}_{CP}^{S,O} = i^R\mathbf{u}_{CP}^{R,O}; \qquad \mathbf{i}^S\mathbf{u}_{CO}^{S,O} = i^R\mathbf{u}_{CO}^{R,O} \tag{6}$$

where: $\mathbf{i}^P$, $\mathbf{i}^R$, $\mathbf{i}^S$ indicate the unity vectors for place of production (P), place of residence (R) and place of commodity market (S).

Both private and governmental savings can be further subdivided. The private savings account can be divided into a balance for households and one for firms. Governmental savings can be divided by level of government (municipality, county and state).

Finally, if the net trade balance is zero, then investment in the region is equal to regional savings. If it is negative, investment is greater than savings, which means that there will be a net inflow of savings and vice versa. It should be noted that there is no direct link between savings and investment in the region, which is touched upon in the following section. Further, the impacts on savings accounts of net interest payments have not been included.

3.2. A Spatial Regional Accounting Model (Two-by-Two-by-Two)

The non-spatial regional accounting model presented above is based upon the *two-by-two* accounting principle, including only such commodity flows as exports, imports and gross factor income flows (both for labour and capital income). In spatial regional accounting, the gross interaction flows are accounted for by including data on the origins and destinations of the flows.

In the case of commodity flows (see earlier), commodity-based activities can be related to place of production and place of residence, linked by the commodity marketplace. These commodity flows are divided into trade in commodities (from place of production to commodity marketplace) and shopping for commodities (from place of residence to commodity market), and including origins and destinations.

In the case of factor income, as described earlier, in the spatial accounting model, incomes are related to place of production (commodity market) and place of residence (supply) linked by the factor marketplace. On the demand side, factor income is accounted for by place of production and place of factor market as well as by type of factor, whereas on the supply side, factor income is accounted for by place of residence and place of factor market.

The treatment of savings and investments is here not as well developed as is possible, because of data constraints. One way around this problem is to use other methods to link regional savings and investment, for example pool-based methods and supra-regional accounts (Round, 1988). Another way forward, though involving stronger data requirements, is to establish a gross flow origin-destination matrix for saving and investments.

Table 1. Classification of commodities according to mobility in the regional economy

		Shopping/Purchases by type: Intermediate consumption/Private consumption/ Governmental consumption/Gross capital formation/ Changes in inventories	
		Mobile	Non-mobile
Trade in commodities	Mobile	Agricultural products, manufacturing industry products	Heating, electricity, domestic services, construction
	Non-mobile	Retailing and wholesaling, services, hotels, restaurants, hospitals, education	Housing, changes in inventories

3.3. Data Construction in a Spatial Regional Accounting System: Mobile and Immobile Commodities

Even though the spatial regional accounting system represents an extension of Regional Accounts, it also brings simplifications in data collection, because certain types of information already exist, which simplifies the data collection task. When introducing the concept of the marketplace for commodities, it also is useful to distinguish between mobile and immobile commodities or components of demand, in obtain to get the best estimates of regional demand and interaction. Immobility is defined as an identity between the geographical locations of production and the commodity market, whereas mobility is a situation where there may be a difference between the two. Table 1 gives an overview of these concepts and provide some examples.

Commodities are traded and transported from place of production to the marketplace for commodities and from marketplace for commodities to the place of residence of the consumer. If transport does not occur on the vertical axis (transport of commodities), immobility in the commodity trade exists, examples being different types of services or, by definition, changes in inventories. Commodities are in turn transported from the marketplace for commodities to the place of residence of the consumer (institution). This shopping activity can be either mobile (transport is involved) or non-mobile (transport is not involved). Home-based consumption such as housing or domestic services, are examples of immobility.

If there is immobility, data can only be estimated from one side. For an example, production of housing services is an immobile commodity both from a trade and a shopping point of view. Therefore, production data on the production of housing services can also be used for estimating data on the demand for housing at the place of the commodity market and the place of residence.

4. Construction of the Danish Interregional SAM

SAM-K is the interregional SAM constructed for Danish regions (Madsen *et al.*, 2001). Regions can be defined at different spatial levels, including municipalities (275), labour market areas (45) and counties (16). The spatial *two-by-two-by-two* principle described above has been the guiding principle for the construction of SAM-K. It is, in principle, designed using the structure shown in Figure 1, being based upon the double spatial entry principle or extended regional accounts (*two-by-two-by-two*), rather than the non-spatial regional accounting principles (*two-by-two*).

The structure of SAM-K follows the basic interregional SAM (Figure 1) with: factor markets and commodity markets; demand and supply; origin (supply) and destination (demand); and incorporating some simplifications and extensions. The basic interregional SAM must be adjusted in order to take into account the nature of the statistics, data collection methods and the structure of the regional economy. On one hand, the model must be broken down and in other aspects it must be merged.

First, the concept of the marketplace for factors does not correspond in general to reality, as noted above. In practice, the place of residence of the production factor (such as labour) can be interpreted as both place of residence and marketplace for factors. Only in very few cases does a geographically defined factor market exist. From a data collection point of view, only registration of place of residence and place production is possible. Therefore, the marketplace for factors has been excluded from SAM-K.

Second, only factor income from labour receives a full treatment. In Denmark, regional data on capital income only exist by place of production. Data on interregional transfer of capital income are still lacking, which makes a comparable treatment to commuting flows involving labour income impossible and identification of the marketplace for capital income difficult to develop. Future developments with respect to treatment of savings and investments and identification of marketplaces for these could include the use of pooling methods or identification of gross flows, referred to above.

Third, there is a need to keep track of economic interactions between institutions. Interaction between households and the governmental sector is important in order to describe the economic strength of households, for example measured by disposable income of households including income transfers from government and the subtraction of taxes. From a data collection point of view, this information does not create any special problems as these payments are assigned to individuals.

Fourth, consumption by institutions (households) both from a decision-making and data collection point of view must be divided into two nested steps. First, consumption is determined at a high level of aggregation, for example food, clothing, transport etc. In the next step, the consumption bundles are further divided into specific commodities. From a decision-making point of view, both the first and second steps are a part of the household decision problem, the sellers (the retail sector) reflecting demand from the households. From a data collection point of view the two steps are also related to two data sources: (i) household expenditure surveys, which often include information at a relatively aggregate level, where household consumption is assigned to the place of residence; and (ii) the retail sector and producers (who pay specific commodity taxes) make a substantial contribution to detailed data on demand, usually through information related to the value added tax and commodity taxes. The same is the case for other types of final demand, such as governmental consumption and gross capital formation, where information is available in the marketplace for commodities.

Fifth, different price concepts are included in different accounts, reflecting the fact that different data sources use different price concepts. In the account for goods and services, total expenditures are measured in market prices. Supply of commodities entering the goods and services account is accounted for in basic prices. Basic prices are defined as the value of production at the factory, not including net commodity taxes paid by the producer. Going from market/buyers prices to basic prices at the place of commodity market involves subtraction of commodity taxes and trade margins, where trade margins also are part of the commodity account.

Sixth, in general, the SAM is constructed using current prices. However, for data concerning production of commodities, values have been deflated to fixed prices at a low level of disaggregation, using national price data. This extension permits analysis of real changes in production over time.

In addition, there are some extensions, such as the transformation from basic prices to market prices and the transformation from institutions to commodities, which in the Danish interregional SAM is divided into two steps: from institutions to components and from components to commodities. Despite this deviation, the Danish system can be represented in a basic four-element system, as shown in Table 2.

4.1. The Basic Interregional SAM and SAM-K

Despite these conceptual deviations, the basic interregional SAM forms a useful framework to describe the data construction procedures and sources used in building SAM-K. Table 2 contains information on the dimensions of SAM-K and the procedures and content of the matrices used to build SAM-K. These cover economic activities related to production and institutions as well as the regional commodity and factor markets. The economic activities associated with production and institutions follow the conventional non-spatial format in the National Accounts. Here the information on production and institutions consists of vectors subdivided by sectors (using axis *J*) and by institutions (using axis *H*). Economic activity associated with the factor and commodity markets builds upon the spatial accounting principle.

The accounts for the factor market have the following structure: (i) the factor market has been divided into supply and demand; (ii) demand for factors of production has been transformed from sectors using axis *J* to factor groups using axis *G* and supply of factors of production has been transformed from Institutions using axis *H* to factor groups using axis *G*; and (iii) demand for factors of production has been transformed from place of production using axis *P* to place of factor markets using axis *Q* and the supply of factors has been transformed from place of residence using axis *R* to place of factor market, using axis *Q*.

Similar transformations take place in the commodity market, where the accounts for the commodity market have the following structure: (i) the commodity market has been divided into supply and demand; (ii) demand for commodities has been transformed from institutions using axis *H* to commodities using axis *I* and supply of commodities has been transformed from sectors using axis *J* to commodities using axis *I*; and (iii) the demand for commodities has been transformed from place of residence using axis *R* to place of commodity market using axis *S* and the supply of commodities has been transformed from place of production using axis *P* to place of commodity market, using axis *S*.

Items (ii) and (iii) in both markets represent collection of data in matrix rather than the vector format, which is used in the non-spatial Regional Accounts. Item (ii) represents a transformation between SAM categories and item (iii) is a geographical specification of the origin and destination of demand and supply in both markets. In the following, construction of the Danish SAM is described with reference to entering data into these

Table 2. The basic interregional SAM set up using the spatial registration system

	Matrix dimension	Bottom Up (BU)/Top Down (TD)	Type of data	Data source
Production	J (NS)	TD	National Accounts	Regional/National Accounts
Factor market				
Demand by factor group (e.g. employment or primary income)	$J \times G$ (NS)	BU	Register-based data	Merged administrative registers: Population, income and tax base registers
Destination of factor demand (e.g. commuting)	$G \times P \times Q$ (S)	BU	Register-based data	Merged administrative registers: Population, income and tax base registers
Supply by factor group (e.g. labour force or income)	$H \times G$ (NS)	BU	Register-based data	Merged administrative registers: Population, income and tax base registers
Origin of factor supply (e.g. commuting)	$G \times R \times Q$ (S)	BU	Register-based data	Merged administrative registers: Population, income and tax base registers
Institutions	H (NS)	TD	National Accounts + survey	Family expenditure survey, tourism expenditure survey
Commodity market				
Demand by commodity (e.g. intermediate consumption, private consumption)	$H \times I$ (NS)	TD	National Accounts + survey	Family Expenditure Survey, tourism expenditure survey, local government account statistics, national Use tables
Destination of commodity demand (e.g. shopping)	$I \times R \times S$ (S)	TD	Survey	National Transport Behaviour survey, tourism expenditure survey, transport cost survey, local government account statistics
Supply by commodity (e.g. production and import from abroad)	$J \times I$ (NS)	TD	National Accounts + survey	Regional/National Accounts, national Make tables
Origin of commodity supply (e.g. interregional trade)	$I \times P \times S$ (S)	TD	Survey	Trade survey, manufacturing firms

(S): spatial, (NS): Non-spatial.

vectors (non-spatial) and matrices (spatial). Full documentation of the principles used to set up the interregional SAM for Denmark is provided in Madsen *et al*. (2001)

4.2. Data on Regional Production, Incomes and Employment by Institution (Regional: Non-spatial)

Data on production by 275 municipalities and 130 sectors is provided by Statistics Denmark, following the principles set out in Eurostat (1996), and is documented in detail in Madsen *et al*. (2001: Chapter 4). Basically, the point of departure is data from the National Accounts by sector, which are used together with different sources to break down the national data to regional data. The methodologies can be divided into use of Top Down (TD) methods where the sum of the regional data is scaled to be consistent with national data and Bottom Up (BU) data where the national sum is by definition equal to the sum of the regional values. Further sources can be divided into statistics for administrative purposes and statistics from surveys (usually undertaken regularly by a government body). Finally there is the issue of whether the statistics are based on population or samples. All in all, ten different methods are used.

Data on institutions (Madsen *et al.*, 2001: Chapter 5) cover at present households and include data on earned income, income transfers, taxes, unemployment and employment, for 275 municipalities and four types of household. The sources of this data include administrative registers, which provide data on income, taxes and employment. The data is Bottom Up, with full population coverage. A central variable is disposable income (related to commodity purchase).

4.3. Data on Factor Markets (Regional: Spatial and Non-spatial)

Madsen *et al.* (2001: Chapter 5) describe these data sources in more detail. Data on production factors include labour force, income and employment. The data are Bottom Up and are obtained from administrative registers, providing data by category on: sectors, factors (distinguishing two gender types, seven age classes, five types of education, and four categories of household composition), place of production and place of factor market (residence). The matrices are filled out with data described above using bottom up principles. Demand goes from place of production to place of residence and supply goes in the reverse direction.

4.4. Data on Commodity Markets (Regional: Non-spatial)

The procedures for estimating commodity balances are described in Madsen *et al.* (2001: Chapters 6–9). First the estimation of supply (in the next section) and demand (in the section after) are described, after which total intra- and interregional trade by commodity is estimated. The geographical patterns of interregional trade flows by commodity are then determined.

For the construction of commodity balances and interregional flows the approach uses regional data on production and demand, which is combined with national assumptions on commodity composition of production and demand. The assumption relating to the national commodity composition is the reason why the approach is termed national. In the construction of the local commodity balances, including the individual components, which enter into the commodity balance to be found in equation (1), the national commodity balance is used (the Top Down approach).

The commodity balances are determined for a number of Danish regions, typically 16 counties plus one extra artificial county, containing economic activities, which cannot easily be allocated to a geographical location (production of crude oil, maritime transport, etc). The 17 regions have been aggregated from the 275 municipalities, which is the lowest level of disaggregation possible in the Danish interregional SAM. The commodity balances at regional level are estimated for 20–30 commodities, which are aggregated from the available data on 130 commodities.

4.5. Regional Supply by Commodity (Regional: Non-spatial)

Supply of commodities consists of local production of commodities, imports of commodities from abroad and interregional commodity import. Local production of commodities is estimated using local sectoral values for gross output combined with sector-specific information on the composition of gross output by commodity (Make matrix).

$$\mathbf{q}_i^P = \mathbf{i}_j \, \mathbf{D}^{NAT} \circ \mathbf{x}^P \tag{7}$$

where $\mathbf{i}_j$ is an aggregation vector by sector j; $\mathbf{D}^{NAT}$ is gross output by commodity i as a share of gross output by sector j at the national level; and $\mathbf{x}^P$ is gross output by sector by place of production P.

The data on gross output by sector and by municipality are obtained from Statistics Denmark (described earlier). Gross output is in basic prices (by definition) and in both fixed and current prices. Data on the composition of gross output by commodity originate from the national Make matrices. The basic approach to estimation of international imports by commodity at the local level is to multiply local demand for a commodity by a (national) import share (of the aggregated local demand). Local demand is calculated as the sum of local intermediate and local final demand in basic prices. It is assumed that there is no major deviation between national and local import shares.

$$\mathbf{z}_i^{S,F} = \mathbf{z}_i^S \circ D_i^{F,NAT} \tag{8}$$

where $\mathbf{z}_i^{S,F}$ are international imports by commodity i by municipality S; $\mathbf{z}_i^S$ is local demand by commodity and by municipality; and $\mathbf{D}_i^{F,NAT}$ gives the import share by commodity at the national level.

Technically, imports are divided into imports for the domestic market and imports for re-export, the latter being smaller than the former. Estimation of interregional imports by commodity is described in the section after next.

4.6. Regional Demand by Commodity (Regional: Non-spatial)

Demand for commodities in any locality consists of local demand, foreign exports and interregional exports. Local demand, by region, by commodity and in total, is, by definition:

$$\mathbf{z}_i^S = \mathbf{u}_{i,IC}^S + \mathbf{u}_{i,CP}^S + \mathbf{u}_{i,CPR}^S + \mathbf{u}_{i,COR}^S + \mathbf{u}_{i,CO}^S + \mathbf{u}_{i,IR}^S + \mathbf{u}_{i,IL}^S \tag{9}$$

where: $\mathbf{z}_i^S$ is local demand by place of commodity market S and by commodity i; $\mathbf{u}_{i,IC}^S$ is intermediate consumption by place of commodity market and by commodity; $\mathbf{u}_{i,CP}^S$ gives private individual consumption expenditure by place of commodity market and by commodity; $\mathbf{u}_{i,CPR}^S$ is private consumption in membership organisations by place of commodity market and by commodity; $\mathbf{u}_{i,COR}^S$ is governmental individual consumption expenditure by place of commodity market and by commodity; $\mathbf{u}_{i,CO}^S$ is governmental collective consumption expenditure by place of commodity market and by commodity; $\mathbf{u}_{i,IR}^S$ is gross fixed capital formation by place of commodity market and by commodity; and $\mathbf{u}_{i,IL}^S$ gives the changes in inventories by place of commodity market and by commodity.

Intermediate consumption by commodity is calculated using information on intermediate consumption by sector and by place of production and the national Use matrix. Each element is calculated as local demand (intermediate consumption by sector and final demand by component) multiplied by a national commodity share (Use matrix).

For intermediate consumption, transformation from sector to commodity takes place in three steps. First, the demand of a sector for a commodity by place of production is given by:

$$\mathbf{U}_{IC}^P = \mathbf{B}_{IC}^{NAT} \circ \mathbf{u}_{j,IC}^P \tag{10a}$$

$$\mathbf{u}_{i,IC}^P = \mathbf{i}_j \mathbf{U}_{IC}^P \tag{10b}$$

where $\mathbf{U}_{IC}^P$ is local demand for intermediate consumption by commodity i, by sector j and by place of production P in buyers' prices; $\mathbf{B}_{IC}^{NAT}$ is intermediate consumption by commodity as share of intermediate consumption, by sector, all at national level; and $\mathbf{u}_{j,IC}^P$ is intermediate consumption by sector by place of production.

Second, intermediate consumption by place of production is transformed from place of production to place of commodity market. Third, intermediate consumption is transformed from market prices to basic prices by subtracting taxes and subsidies on products and trade margins paid by the producer:

$$\mathbf{u}_{i,IC}^{S,BP} = \mathbf{u}_{i,IC}^S - \mathbf{sipu}_{i,IC}^S - \mathbf{sigu}_{i,IC}^S - \mathbf{rmu}_{i,IC}^S - \mathbf{wmu}_{i,IC}^S \tag{11a}$$

$$\mathbf{sipu}_{i,IC}^S = \mathbf{SIPUQ}_{i,IC}^S \circ \mathbf{u}_{i,IC}^S \tag{11b}$$

where $\mathbf{u}_{i,IC}^{S,BP}$ is local demand for intermediate consumption by commodity i by place of commodity market S in basic prices (BP); $\mathbf{u}_{i,IC}^S$ is local demand for intermediate consumption by commodity by place of commodity market S in market prices; $\mathbf{sipu}_{i,IC}^S$ are commodity taxes by place of commodity market and commodity; $\mathbf{sigu}_{i,IC}^S$ are value added taxes by place of commodity market and commodity; $\mathbf{rmu}_{i,IC}^S$ are retail margins by place of commodity market and commodity; $\mathbf{wmu}_{i,IC}^S$ are wholesale margins by place of commodity market and commodity; and $\mathbf{SIPUQ}_{i,IC}^S$ are commodity taxes by place of commodity market and commodity as share of intermediate consumption.

Intermediate consumption by municipality by 130 sectors ($\mathbf{u}_{j,IC}^P$) is estimated by Statistics Denmark using their own local production data. In the estimation of regional commodity balances, the 130 sectors are aggregated, normally into 12–20 sectors. The data on aggregate commodity composition by sector, in equations (10a) and (10b), are taken from national Use tables. The number of commodities used is normally 20–30.

Shopping for intermediate consumption is estimated using transport survey data. Estimation of commodity taxes and trade margins is based upon national commodity tax rates and national shares in the case of wholesaling margins and regional shares in the case of retail margins. The corresponding calculations are made for the components of final demand.

Exports to the Rest of World are distributed as exports from localities in proportion to gross output by commodity, by place of production. The basic approach to estimation of international exports is to multiply gross output with a national export share:

$$\mathbf{z}_i^{P,F} = \mathbf{q}_i^P \circ \mathbf{B}_i^{F,NAT} \tag{12}$$

where $\mathbf{z}_i^{P,F}$ are international exports by commodity i by place of production P; and $\mathbf{B}_i^{F,NAT}$ is the share of exports in production by commodity at the national level.

The national approach in this field also relies on the assumption that location close to a border does not affect export shares. Modification of this assumption would have to be based upon survey data. Technically, exports are divided into exports produced domestically and re-exports, the latter imported from abroad. Interregional export by commodity is dealt with in the following section.

4.7. *Estimation of the Regional Commodity Balances (Regional: Non-spatial)*

The geographical transformation from place of production to place of commodity market follows, although the framework remains, strictly speaking, non-spatial. In Table 3 the procedures used to construct intraregional and interregional trade are presented. The numbers 1–5 in the table indicate the sequence of steps, used and the arrows show how variables are calculated from others. From the previous section, the value (1) in Table 3 shows which information has been obtained from the calculations of commodity balances using the national approach. On the basis of this information, the following procedure has been used to estimate the full trade matrix. In step 2, total supply and total demand have been calculated:

$$\mathbf{z}_i^{P,excl.O} = \mathbf{q}_i^P + \mathbf{z}_i^{S,F} \tag{13a}$$

$$\mathbf{z}_i^{S,excl.O} = \mathbf{u}_i^S + \mathbf{z}_i^{P,F} \tag{13b}$$

Table 3. Intra regional, interregional and international trade

	The region itself	Other regions	Rest of the World	Total	From other regions: Preliminary estimate
The region itself	$\mathbf{z}_i^P$ (4)	$\mathbf{z}_i^{P,O}$ (5)	$\mathbf{z}_i^{P,F}$ (1)	$\mathbf{q}_i^P$ (1)	↓
Other regions	$\mathbf{z}_i^{S,O}$ (5)			$\mathbf{z}_i^{P,excl.O}$ (2)	$\mathbf{Z}_i^{S,O,preliminary}$ (3)
Rest of the World	$\mathbf{z}_i^{S,F}$ (1)			$\mathbf{z}_i^{S,F}$ (1)	↑
Total	$\mathbf{u}_i^S$ (1)	$\mathbf{Z}_i^{S,excl.O}$ (2) →	← $\mathbf{Z}_i^{P,F}$ (1)		
To other regions: Preliminary estimate		$\mathbf{z}_i^{P,O,preliminary}$ (3)			

where $\mathbf{z}_i^{P,excl.O}$ is total supply, excluding interregional imports, by commodity *i*; and $\mathbf{z}_i^{S,excl.O}$ is total demand, excluding interregional exports, by commodity.

In step 3 total supply, excluding interregional imports, has been compared to total demand, excluding interregional exports, in order to calculate a preliminary value for interregional imports and exports by commodity:

$$\text{if } \mathbf{z}_i^{P,excl.O} > \mathbf{z}_i^{S,excl.O} \text{ then } \mathbf{z}_i^{P,O,preliminary} = \mathbf{z}_i^{P,excl.O} - \mathbf{z}_i^{S,excl.O} \tag{14a}$$

$$\text{if } \mathbf{z}_i^{P,excl.O} \leq \mathbf{z}_i^{S,excl.O} \text{ then } \mathbf{z}_i^{S,O,preliminary} = \mathbf{z}_i^{S,excl.O} - \mathbf{z}_i^{P,excl.O} \tag{14b}$$

where $\mathbf{z}_i^{P,O,preliminary}$ are interregional exports by commodity i – preliminary values; and $\mathbf{z}_i^{S,O,preliminary}$ are interregional imports by commodity – preliminary values.

In the fourth step, intra regional supply and demand have been calculated on the basis of the preliminary values of interregional import and export by commodity:

$$\mathbf{z}_i^{P,preliminary} = \mathbf{q}_i - \mathbf{z}_i^{P,F} - \mathbf{z}_i^{P,O,preliminary} \tag{15}$$

where $\mathbf{z}_i^{P,preliminary}$ is intra regional supply by commodity i – preliminary value.

In the last step, two-way trade (cross hauling) has been included in the estimation of interregional trade flows:

$$\begin{aligned} &\text{if } \mathbf{z}_i^{P,O,preliminary} = 0 \text{ then } \mathbf{z}_i^{P,O} = \mathbf{z}_i^{P,O,preliminary} + \gamma \cdot \mathbf{q}_i^P \text{ and} \\ &\qquad \mathbf{z}_i^{S,O} = \mathbf{z}_i^{S,O,preliminary} + \gamma \cdot \mathbf{q}_i^P \end{aligned} \tag{16a}$$

$$\begin{aligned} &\text{if } \mathbf{z}_i^{S,O,preliminary} = 0 \text{ then } \mathbf{z}_i^{S,O} = \mathbf{z}_i^{S,O,preliminary} + \gamma \cdot \mathbf{u}_i^S \text{ and} \\ &\qquad \mathbf{z}_i^{P,O} = \mathbf{z}_i^{P,O,preliminary} + \gamma \cdot \mathbf{u}_i^S \end{aligned} \tag{16b}$$

where $\mathbf{z}_i^{P,O}$ is interregional export by commodity *i*; γ is the cross-hauling parameter (see below); and $\mathbf{z}_i^{S,O}$ is interregional import by commodity.

The exogenous variable γ is a cross-hauling parameter that varies between groups of commodities and determines the additional interregional trade that is due to cross-hauling. Note that γ is not equal to the share of the region's production that meets its own demand, as the level of cross-hauling depends on local production and local demand, respectively. The proportion of the region's production that meets its own demand is the result of the estimation procedure. If the region is a net supplier, the additional interregional trade (cross-hauling) is calculated by multiplying local production by γ. If the region is a net demander, the local demand is multiplied by γ. In Jensen-Butler *et al.* (2004), a trade survey is used to estimate γ for seven industrial commodities.

Even though the equations for calculation of the different balances are the same for all commodities, there is also an implicit difference in the treatment of mobile and immobile commodities. Immobile commodities are characterised by the fact that local demand and local production are equal, being located in the same geographical unit. This is a definition that can be compared with tradable and non-tradable commodities. Tradable commodities are those that compete with the same or similar products from the Rest of the World. Non-tradable commodities are those that are protected from this competition, either because of their characteristics or because of their fundamental immobility. Commodities that are non-tradable at the international level may well be tradable at lower levels of spatial aggregation. Thus, the concept of immobile commodities is narrower than non-tradable commodities. For immobile commodities, intraregional trade is equal to supply, which in turn is equal to demand. For mobile commodities, intraregional trade is calculated as follows:

$$\mathbf{z}_i^P = \mathbf{q}_i^P - \mathbf{z}_i^{P,F} - \mathbf{z}_i^{P,O} \tag{17}$$

where $\mathbf{z}_i^P$ is intra regional supply by commodity i.

Now a system has been established to estimate intraregional-, interregional and international trade flows. The distribution between intra- and inter-regional trade is determined by the share of cross-hauling in domestic trade.

4.8. Interregional Trade Flows by Commodity (Regional: Spatial)

From the procedure described in the previous section, two sets of information are obtained. First, supply for local market ($\mathbf{z}_i^P$) by commodity is calculated. In an intra- and interregional trade matrix, this information is located at the diagonal and shows the region's sales to the region itself or the region's demand for commodity produced in the region itself. Second, exports to other regions ($\mathbf{z}_i^{P,O}$) and imports from other regions ($\mathbf{z}_i^{S,O}$) have been determined. These data are the margin sum of the off-diagonal cells in the trade matrix.

On the basis of these margin sums the final step is the determination of the detailed off-diagonal data in the intra- and interregional trade matrix, in other words calculation of interregional trade flows, using the calculated totals for interregional export ($\mathbf{z}_i^{P,O}$) and imports ($\mathbf{z}_i^{S,O}$) by region and by commodity. These values are given by the procedure described in the previous section. There are different approaches to estimation of interregional trade flows. The approach used here is to employ entropy maximising procedures, including, as a special case, the linear programming solution:

$$\mathbf{z}_i^{P,S} = \mathbf{A}_i^P \cdot \mathbf{B}_i^S \cdot \mathbf{z}_i^{P,O} \cdot \mathbf{z}_i^{S,O} \cdot \mathbf{e}^{-\beta_i \mathbf{c}_i^{P,S}} \tag{18}$$

with $A_i^P = 1/\sum_S \mathbf{B}_i^S \cdot \mathbf{z}_i^{S,O} \cdot e^{-\beta_i \mathbf{c}_i^{P,S}}$ and $B_i^S = 1/\sum_P A_i^P \cdot \mathbf{z}_i^{P,O} \cdot e^{-\beta_i \mathbf{c}_i^{P,S}}$, and where: $\mathbf{z}_i^{P,S}$ is interregional trade by place of production P and place of commodity market S, by commodity i; $\mathbf{A}_i^P$, $\mathbf{B}_i^S$ are balancing factors, by commodity; $\mathbf{c}_i^{P,S}$ is transport cost for the transport of the interregional traded commodities from place of production to place of residence, by commodity; and β_i the deterrence parameter in the entropy maximising model by commodity.

The entropy maximising procedures were also used in the construction of data on interregional trade flows by sector in Denmark used in the AIDA-model (Jensen-Butler and Madsen, 1996). These entropy maximising procedures have been used in the estimation of the interregional trade flows in the present version of SAM-K. Data on interregional transport cost[3] from the Danish Department of National Roads have been used in the estimation of interregional trade. The distance deterrence parameter β varies between groups of commodities and has been estimated for a range of industrial products manufactured by Danish firms (Jensen-Butler *et al.*, 2004). The use of entropy maximising principles involving a distance deterrence function implies that distance related transportation costs play a central role in determining the pattern of trade flows.

5. Data Quality Considerations

Regional accounting as described here uses four primary sources of data, as shown in Table 2. First, there are data obtained from register-based data sets, usually maintained and updated continuously by public authorities. Second, there are survey data of firms and households based on total enumeration. Third, there are survey data based upon sampling. Fourth, there are data, which are calculated, designed to provide data for areas not covered by the three other sources. These are often calculated using best practice modelling, where the data construction model estimates the data on the basis of limited information using National Accounts and a set of constraints, as for example for the interaction data described in the third section.

In the case of Denmark, the first source of data provides information of very high quality for a substantial part of the interregional SAM, including most of the labour market (see Table 2). Even for countries where census data (which corresponds to the second type of data) must be used in data construction, this information, often in extended form, is usually available for specific years.

Sample-based surveys, such as Family Expenditure Surveys can be regarded as reasonably reliable. If these are combined with register-based data (for example disposable income and earned income) and national totals to be found in the National Accounts, then data quality (for example for private consumption) can be further improved. This has been undertaken in the Danish case, and a similar approach is possible in countries that do not have such register-based data, using census data and the National Accounts.

The fourth type of data is constructed using models and National Accounts constraints. One example in the Danish case where this approach has been used is in establishing commodity and trade balances at the regional level. Discussion of data quality in relation to this type of data can be found in Madsen and Jensen-Butler (1999), where we conclude that in relation to the estimated values of most variables at regional and interregional levels, relative and absolute degrees of uncertainty are in general low. However, one important conclusion of this paper has since been modified empirically, namely that, in all circumstances, the highest level of disaggregation possible should be used to ensure accuracy. Normally it is assumed that this type of data modelling should be undertaken at the most disaggregated level possible (for example in terms of spatial unit, industry or commodity) and hereafter aggregated into a higher-level data set, which meets the data needs for the modelling exercise in question. However, recent research (Jensen-Butler *et al.*, 2004) indicates that this is not necessarily a general requirement. For certain types of interaction data, for example interregional rather than intraregional trade flow data, there seems to be little advantage gained from the use of a high level of disaggregation.

There are costs involved in following a disaggregated approach to data modelling, including costs of accessing the data to be used in the modelling exercise, programming, consistency checks and data processing. These costs have to be compared with the benefits that are assumed to exist, principally the assumption that better data are obtained by proceeding in this way. In the Danish case, a high level of disaggregation is used to estimate intraregional interaction, whilst a lower level of disaggregation can be used for interregional interaction. There is no reason to assume that this finding cannot be generalised to other countries.

6. Conclusion

The paper shows that construction of interregional SAMs involves two steps to improve the Regional Accounts, as recommended by Eurostat (1996). First, the balancing procedures of the National Accounts for commodities and factors have to be transferred to the Regional Accounts. Second, procedures to construct spatial data on interaction in the regional economy should also be included in the data-building process. Both improvements build on the novel geographical concepts – place of production, place of residence, place of commodity market and place of factor market – identified in the paper. The concrete procedures used to set up a Regional Account with a spatial dimension for Denmark have been presented.

The Danish interregional SAM has used the spatial *two-by-two-by-two* accounting methods described above. Even though the construction of the spatial interregional SAM appears to be an major undertaking, the Danish example shows that introducing an extension of the conventional non-spatial to spatial accounting methods is not unrealistic, if suitable and reasonable limitations are accepted, such as is the case with the treatment of capital income. Even for countries with limited data, it is possible to set up a spatial SAM based on an explicit spatial dimension.

Notes

1. 'Spatial' includes both regional and local levels, corresponding to the *inter* and *intra* regional levels. The regional level typically involves trade and tourism, but when incorporating shopping and commuting, it is necessary to construct accounts at the local (sub-regional) level.
2. The commodity balance system is set up in basic prices, where supply equals demand in basic prices. However, the commodity balance also contains information on components of demand and demand in both basic prices and market prices, including data on trade margins and commodity taxes. Therefore, the demand side is estimated in two steps. First, demand is converted from components to commodities, and in the second step, market prices are transformed to basic prices. The commodity balance is estimated in both fixed and current prices, as both supply and demand are in both fixed and current prices.
3. In order to avoid values in the diagonal, the intraregional transport cost is set at a very high level (in principle infinite).

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Section 10:

Make and Use Approaches to Regional and Interregional Accounts and Models

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Make and Use Approaches to Regional and Interregional Accounts and Models

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ABSTRACT *Institutional, or sector-by-sector input–output tables have traditionally been used in regional and interregional modelling. This paper examines the origins of this tradition and argues instead, both theoretically and empirically, for the integration of make and use submodels within models of production, demand and interregional trade, outlining the manner in which they can be integrated. Further, it is argued that structural rather than reduced-form models represent a sounder theoretical base. Finally, a Danish interregional model (LINE) based on a social accounting matrix framework that employs these principles is presented. The paper also deals with the issue of data construction at the regional and interregional levels, based on the make and use approach. It is argued that when data are constructed at a low level of sectoral and spatial aggregation under accounting consistency constraints, data quality and validity are high.*

KEYWORDS: *Make and use, interregional trade, commodity balance, regional accounts*

1. Introduction

In regional and interregional modelling, institutional, or sector-by-sector input–output (IO) tables have traditionally been developed and used as the core of the model. From a theoretical point of view, it is preferable to base such models on 'make and use' submodels (sector-by-commodity and commodity-by-sector models), because, in theoretical terms, a model developed using these elements will be closer to the theories of production and consumption which underlie the overall model. In addition, it is easier to formulate and understand the implications of the assumptions of a model if these are made explicit by the use of models in structural form that involve make and use submodels, instead of using a reduced-form model (the institutional IO model). Changes in interaction between the different elements of the model and changes in actors' behaviour are also more consistently modelled if the model is developed in structural form.

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In addition, if the structural form of the model is used in the interregional case, then there is closer correspondence to underlying trade theory, as trade takes place with commodities rather than with the output of sectors. Interregional models have traditionally also had an institutional form, with interregional trade coefficients being calculated for interregional trade between sectors.

In this paper, the structure of an interregional model based on make and use matrices is presented. In terms of data, both survey and non-survey methods are proposed to estimate commodity and trade flows based on make and use matrix approaches. The methods derive from the principle of disaggregation under consistency restrictions, which involves as high a degree of spatial and sectoral disaggregation as possible in the estimation procedure for commodity and trade balances, at the same time as complying with accounting principles related to consistency. By using these disaggregation and consistency principles in the construction of regional make and use matrices as well as commodity and trade flows, data quality is improved markedly.

One advantage of the make–use approach is that it is based directly on the methods used by agencies in assembling national accounts. The supply and use framework is used to collect economic data, which are integrated into a common (System of National Accounts; SNA) framework. Institutional approaches then build on this theoretical and data-collection framework. Thus, make and use approaches relate more directly to the theoretical framework that underlies data collection for national and regional accounts and, as a consequence, to the data themselves. In constructing regional data using non-survey methods, it is better to use directly the data which have been collected, rather than data which have been subjected to transformation, as is the case with institutionally based accounts.

A further advantage of this make–use approach is that it is more easily comprehensible for potential and actual users of the model apparatus, being closer to reality. Furthermore, there is a potentially broader field of application of such commodity–sector-based models as compared with traditional sector-based models, such as in the field of resource and commodity flows and environmental modelling. Finally, the cost of this make–use and disaggregation approach, in terms of data, is not greater than those of the more traditional institutional approaches.

These issues are discussed in more detail in this paper. Section 2 examines the theoretical background and tradition associated with both institutional and structural approaches. Section 3 deals with the traditional institutional IO approach in single-region modelling as compared with the disaggregated make–use approach. In Section 4, the institutional approach to interregional modelling is related theoretically to the make–use approach, and problems of data construction are discussed. In Section 5, the structural approach to interregional modelling, based on commodities, is examined and a Danish model is used to illustrate the discussion. Within this section, the structure of the model is examined, followed by a presentation of the construction of model variables on the basis of regional make and use matrices. Data construction using the national non-survey approach is then discussed. The final part of Section 5 discusses survey approaches in relation to the national non-survey approach outlined already. In Section 6, data validity using the national non-survey approach is discussed in light of the principles of consistency and high levels of disaggregation.

2. Traditions in Data Construction and Modelling in Interregional IO Analysis

Regional and interregional IO modelling has generally been based on the Leontief tradition, where analysis has involved either the Leontief inverse matrix, or the sector-by-sector square matrix of intermediate consumption (**A**) and the sector-by-component matrix of final demand (**F**). This is illustrated later in the standard single-region formulation in equations (1)–(4).

As will be argued, there appear to be considerable advantages in building commodity and trade models in a structural form, incorporating use and make matrices and interregional trade commodity trade models. Despite these advantages, it is interesting to reflect on why the analytical and reduced-form approach has dominated regional and interregional modelling.

First, regional and interregional modelling has usually followed in the footsteps of national IO modelling traditions, involving the use of the Leontief inverse in analytical solutions. For example, in Denmark, for many years, national macro-economic models have incorporated the Leontief inverse directly (for example, the two national macro-economic models ADAM and SMEC). The national statistical office Statistics Denmark has, for over 20 years, published Leontief multipliers and national IO tables on an institutional basis. In reality, at the national level, and following the 1968 United Nations system, sector-by-sector IO tables are based on make and use matrices. Thus, the basic concepts of a make–use approach have existed for many years in relation to data construction, but have only slowly gained acceptance in modelling.

In the 1980s, two significant developments occurred. The first was that the **A** matrix was incorporated directly into the model, and iterative solutions for the model were employed rather than using the Leontief inverse. This can be seen in a number of Danish studies (Dam, 1995; Jensen-Butler & Madsen, 1996a,b; Madsen, 1991). Secondly, there was the development of the social accounting matrix (SAM) approach, involving explicitly make and use matrices (see for example, Hewings & Madden, 1995). In the typical form, sectors demand commodities for intermediate consumption and the institutional sector demands commodities for final demand (the use matrix). Commodities are also purchased from producing sectors (the make matrix). The SAM approach first entered Danish regional modelling in the mid-1990s (Madsen *et al.*, 1997).

Further, the data requirements for a structural model are perceived to be much greater, which has certainly acted as a deterrent to their development in a regional context. However, it must be remembered that the UN national accounting standards established in 1968, which are based on make and use matrices, were also promoted by Third World countries, where data are generally scarce. In addition, some of the first SAM modelling exercises, which included make and use submodels, were undertaken for Third World countries (Hewings & Madden, 1995). Make and use matrices have existed at the national level in many countries for a number of years, not least because of the UN standards established in 1968. Therefore, it is perhaps surprising that the regional tradition has almost exclusively been based on the sector-by-sector approach.

In the field of interregional modelling, the main schools have taken as their point of departure institutional tables and models. In the UK and 'Anglo-Saxon' traditions of regional and interregional IO modelling, the point of departure for semi-survey or non-survey approaches to model construction has been the national

IO table. The main focus of interest has been on the supply side. First, supply is treated on a sectoral basis, starting from the national input coefficients, which are sectoral. Next, supply is divided into supply coefficients from the region itself, from other regions and from abroad. Using survey methods, information on firms' purchases by sector and place of origin is collected. Using non-survey methods, national input coefficients are combined with different indicators of regional supply capacity, such as location quotients or cross-industry quotients, which are used to estimate the regional trade coefficients in the interregional/interindustry transactions matrix. Following on from this regional approach, the consequences for the interregional case are that trade relations have also been estimated sectorally (see for example, Oosterhaven, 1981). These principles have also been followed in the Danish regional and interregional IO modelling tradition (Jensen-Butler & Madsen, 1996a, b). Semi-survey methods include those which depend partly on the existence of supply and demand information on an aggregate level, and partly on survey-based information concerning key sectors and firms in a region.

The Dutch tradition has departed from the UK and 'Anglo-Saxon' tradition in certain important respects. First, the fact that firms generally tend to be better informed about the destinations of their sales rather than the origins of their purchases has led to the development of biregional tables and related estimation procedures (Boomsma & Oosterhaven, 1992). This avoids the use of coefficient-based methods for estimating the coefficients of a regional IO table, with their inherent tendency to overestimate intra-regional transactions. The method also gives better opportunity for consistency checks, using double-entry principles. There is also an example of an early Danish biregional analysis (Holm, 1984). Secondly, there has been growing interest in the use of commodity-based analysis (Oosterhaven, 1984).

Common elements in all approaches are the use of sector-by-sector frameworks in the transactions and trade matrices, and the use of analytical solutions based on the Leontief inverse. It is tempting to suggest that the use of the Leontief inverse through several decades, rather than its replacement by iterative methods or structural models, is both because of the analytical elegance of the Leontief solution and a conceptual lock-in. However, this is beginning to change. Jackson (1998) examines the construction of regional commodity-by-industry accounts with an approach which is based on national accounts. He then discusses the transition from the construction of accounts to regional modelling.

Eding and Oosterhaven (1996) have advocated the use of the rectangular or commodity-based approach in modelling trade flows. Following the principles outlined a few years earlier, it is argued that export data are much more reliable than import data, and that biregional principles ensure both consistency and avoidance of the problems in using coefficient methods. This approach requires only regional use matrices in a biregional framework.

3. Institutional and Make–Use Approaches in Single-region IO Modelling

In this section, a brief comparison is made between the institutional and make–use approaches in single-region modelling.

From the 1940s onwards, regional IO modelling has been dominated by a set of theoretical and analytical concepts derived from the pioneering work of Leontief (1951, 1966). This legacy, while having created important theoretical and methodological breakthroughs during the last 50 years, has also contributed to structuring the questions asked and the analytical frameworks developed.

The theoretical basis of this type of approach is an institutional sector-by-sector transactions matrix, i.e.

$$\mathbf{A}=\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & & & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix} \tag{1}$$

and an $n \times m$ final demand matrix, i.e.

$$\mathbf{F}=\begin{pmatrix} f_{11} & f_{12} & \dots & f_{1m} \\ f_{21} & f_{22} & \dots & f_{2m} \\ \vdots & & & \vdots \\ f_{n1} & f_{n2} & \dots & f_{nm} \end{pmatrix} \tag{2}$$

In model terms, the following structural form is used in the intraregional case:

$$\mathbf{x}=\mathbf{Ax}+\mathbf{Ff} \tag{3}$$

where the following notation is used:

- $\mathbf{x}$ is the vector of gross output (sectors);
- $\mathbf{A}$ is the matrix of technical and trade coefficients (sector $\times$ sector);
- $\mathbf{f}$ is the vector of final demand (components of final demand);
- $\mathbf{F}$ is the matrix that transforms final demand by component to final demand by sector (sector $\times$ components of final demand).

This is reformulated in a reduced form as

$$\mathbf{x}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{Ff} \tag{4}$$

The Leontief inverse $(\mathbf{I}-\mathbf{A})^{-1}$ is usually regarded as the analytical solution of the institutional IO table, where it is customarily used to estimate the multiplicative effects of external demand shocks.

The institutional IO model is itself in reduced form, because it is actually derived from two separate models represented by the use and the make matrices, which are commodity-by-sector/component and sector-by-commodity matrices respectively. The make and use matrices are rectangular, with n sectors, j components of final demand and m commodities. The make matrix shows the distribution of sectoral production by commodity, while the use matrix shows consumption of commodities by sectors of production and components of final demand.

In the one-region case, the derivation is:

$$\mathbf{x}=\mathbf{D}(\mathbf{B}^{ic}\mathbf{x}+\mathbf{B}^{fd}\mathbf{f}) \tag{5}$$

$$\mathbf{x}=(\mathbf{I}-\mathbf{DB}^{ic})^{-1}\mathbf{DB}^{fd}\mathbf{f} \tag{5a}$$

where we have the following notation:

- $\mathbf{D}=\mathbf{V}(\mathbf{Q})^{-1}$ with $\mathbf{V}$ being the make matrix and $\mathbf{Q}$ a diagonal matrix of gross output by commodity;
- $\mathbf{B}^{ic}=\mathbf{U}^{ic}(\mathbf{X})^{-1}$ with $\mathbf{U}^{ic}$ being the use matrix for intermediate consumption and $\mathbf{X}$ a diagonal matrix of gross output by sector;

$\mathbf{B}^{fd} = \mathbf{U}^{fd}(\mathbf{F})^{-1}$ with $\mathbf{U}^{fd}$ being the use matrix for final demand and $\mathbf{F}$ a diagonal matrix for final demand by component.

Note that, in relation to equation (4), we have:

$$\mathbf{A} = \mathbf{D}\mathbf{B}^{ic} \tag{6}$$

$$\mathbf{F} = \mathbf{D}\mathbf{B}^{fd} \tag{6a}$$

Thus, the logic of the model is the sequence S → C → S, where S denotes sector and C denotes commodity. Both the model and the data used rest on an industry-based technology assumption (Miller & Blair, 1985, p. 149).

Thus, the reduced-form model in equation (4) can be reformulated as equation (5a). This means that the IO model can also be formulated as a structural IO model using a commodity-by-commodity matrix. Equations (6) and (6a) simultaneously constitute model equations in structural form and procedures for the calculation of the institutional IO table.

4. The Interregional Case: The Institutional IO Model and Sectoral Trade Model

In the interregional case, the dominant tradition (following on from the construction of regional models) has also been to build on the institutional form of the model. This has led to a number of theoretical and practical problems, which are examined in the following.

4.1. The Institutional Interregional IO Model and Use and Make Matrices

Corresponding to the single-region approach outlined in equations (4)–(6) is the interregional (IR) model, formulated in reduced form and based on the institutional approach, i.e.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A}^{IR})^{-1}\mathbf{F}^{IR}\mathbf{f} \tag{7}$$

where $\mathbf{A}^{IR}$ is a matrix of coefficients with dimensions (sector × region) × (sector × region); and $\mathbf{F}^{IR}$ is a matrix of coefficients with dimensions (sector × region) × (component of final demand × region).

As in the one-region case, the interregional model can be formulated in structural form based on the make and use approach, i.e.

$$\mathbf{x} = \mathbf{D}\mathbf{T}(\mathbf{B}^{ic}\mathbf{x} + \mathbf{B}^{fd}\mathbf{f}) \tag{8}$$

$$\mathbf{x} = (\mathbf{I} - \mathbf{D}\mathbf{T}\mathbf{B}^{ic})^{-1}\mathbf{D}\mathbf{T}\mathbf{B}^{fd}\mathbf{f} \tag{8a}$$

where $\mathbf{T}$ is an interregional trade matrix in commodities.

Note that, in relation to equation (7), we have:

$$\mathbf{A}^{IR} = \mathbf{D}\mathbf{T}\mathbf{B}^{ic}$$

$$\mathbf{F}^{IR} = \mathbf{D}\mathbf{T}\mathbf{B}^{fd}$$

Here, the logic of the model is S → C → C → S, again where S denotes sector and C denotes commodity. This corresponds to a supply pool approach, as the trade model is assumed to be identical for all types of use of a given commodity, irrespective of sector (in the case of intermediate consumption) and component of final demand (in the case of private consumption, etc.). This interregional formulation is examined in more detail next.

4.2. Model Structure

The structural form of the interregional institutional model is shown in Figure 1.

The horizontal axis shows a division of economic activity, depending on whether it occurs at the place of production or the place of demand. This is initially a conceptual subdivision of different regions. In an interregional model, inside the categories of place of production and place of demand, there is more than one region. Given *n* sectors and *r* regions, the matrices of gross output and intermediate consumption have the dimensions $n \times r$, while the interregional trade matrix for intermediate commodities has the dimensions $(n \times r) \times (n \times r)$. The vertical axis has two divisions: sectors of production and components of demand. Starting in the bottom right-hand cell, with components of demand by place of demand, these are transformed via the matrix **F** to sectoral demand, which then goes on through an interregional trade model from place of demand to place of production, with a feedback loop that involves intermediate consumption.

The link between demand and production (gross output) in the institutional interregional model in non-reduced form is as follows:

$$\mathbf{x} = \mathbf{A}^{IR}\mathbf{x} + \mathbf{F}^{IR}\mathbf{f} \tag{9}$$

Trade in this type of model takes place between sectors in different regions, or

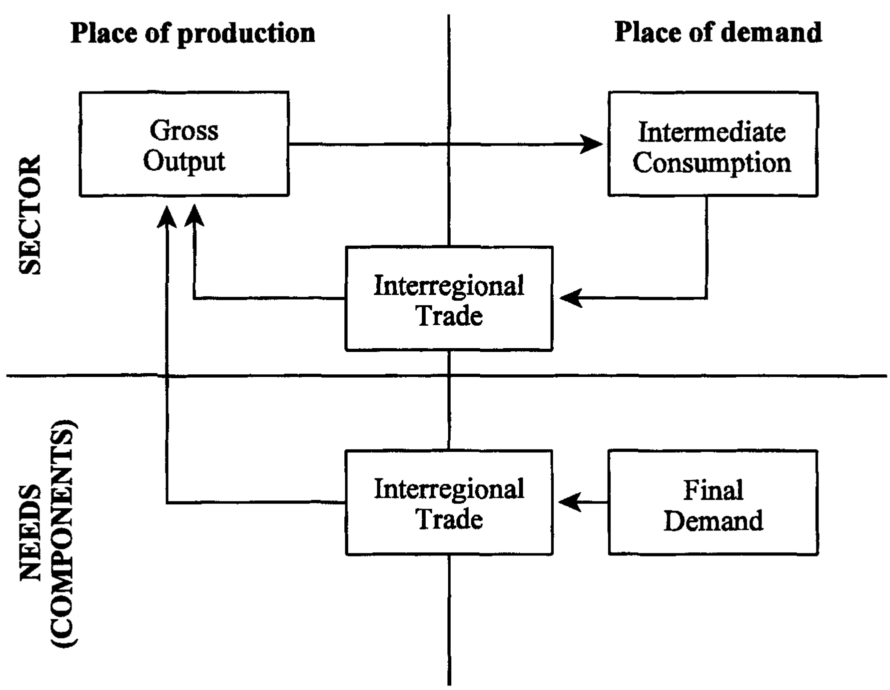

Figure 1. Interregional model based on the institutional (sector-by-sector) approach and trade in sectoral product.

between sectors and components of final demand in different regions, where the underlying logic is sectorally based (see Jensen-Butler & Madsen, 1996a,b; Oosterhaven, 1981; Polenske, 1980 and in a dynamic form Campisi *et al.*, 1990).

This conceptual framework, based on an institutional approach, has been used widely both in regional accounting and in regional modelling. Viewed theoretically, this is perhaps less than satisfactory. Underlying trade theory, such as factor endowment theories of the Heckscher–Ohlin type and theories of intra-industry trade, build on trade in commodities rather than sectoral output. Commodity characteristics, including commodity prices, are the principal determinants of trade patterns.

The structural form of the IO model shown in Figure 1 also indicates how a numerical solution of the model can be used based on this structural form, as an alternative to the analytical solution based on the Leontief inverse. This is the round-by-round numerical solution which converges on the same solution as the Leontief inverse. Although more laborious and analytically less elegant, it permits greater theoretical and methodological flexibility, because coefficients in the IO structure can be modified during the solution process.

4.3. Data Construction

In relation to data construction, the institutional approach applied to the interregional case cannot be based on a straightforward application of make and use matrices, but must resort to complicated, 'opaque' methods.

Following the concept outlined by Isard (1951) that a sector in two different regions be treated as two different sectors, applying make and use principles in the interregional case (see equations (6) and (6a)) will give biased and, indeed, trivial solutions, because trade will be distributed proportionally between regions in relation to generation and attraction, while transport and other costs, such as border barriers, will have no influence on the distribution.

The sum of interregional exports by sector can be determined residually as

$$\mathbf{Z}_{\mathrm{E}}^{\mathrm{RO,DIS}} = \mathbf{x}^{\mathrm{DIS}} - (\mathbf{A}^{\mathrm{R,DIS}}\mathbf{x}^{\mathrm{DIS}} + \mathbf{F}^{\mathrm{R,DIS}}\mathbf{f}^{\mathrm{DIS}}) \tag{10}$$

where $\mathbf{Z}_{\mathrm{E}}^{\mathrm{RO,DIS}}$ denotes interregional export (to other regions (O)) by sector and by place of production (R) at a sectorally disaggregated level; and DIS refers to a sectorally disaggregated level.

Interregional imports can be determined as:

$$\mathbf{Z}_{\mathrm{E}}^{\mathrm{SO,DIS}} = \mathbf{IA}^{\mathrm{R,DIS}}\mathbf{x}^{\mathrm{DIS}} + \mathbf{IF}^{\mathrm{R,DIS}}\mathbf{f}^{\mathrm{DIS}} \tag{11}$$

where $\mathbf{Z}_{\mathrm{E}}^{\mathrm{SO,DIS}}$ denotes interregional imports (from other regions (O)) by sector and by place of demand (S) at a sectorally disaggregated level; and $\mathbf{IA}^{\mathrm{R,DIS}}$ and $\mathbf{IF}^{\mathrm{R,DIS}}$ denote interregional imports as a share of gross output (final) demand, by sector (component) of final demand and by place of demand (S) at a sectorally disaggregated level.

The disaggregated single-region own-consumption $(\mathbf{A}^{\mathrm{R}}, \mathbf{F}^{\mathrm{R}})$ and import matrices $(\mathbf{IA}^{\mathrm{R}}, \mathbf{IF}^{\mathrm{R}})$ are conventionally estimated using methods based on location quotients and national technical coefficients, fulfilling the constraints:

$$\mathbf{A}^{\mathrm{NAT}} = \mathbf{A}^{\mathrm{R}} + \mathbf{IA}^{\mathrm{R}}$$

$$\mathbf{F}^{\mathrm{NAT}} = \mathbf{F}^{\mathrm{R}} + \mathbf{IF}^{\mathrm{R}}$$

Given the resulting vectors of interregional exports and imports by sector, interregional trade patterns by sector can be estimated using entropy-maximizing techniques based on a matrix of interregional generalized transport costs related to trade in the specific sector. Jensen-Butler and Madsen (1996a) provide an illustration of this procedure.

5. Interregional IO Models: In a Structural Form and Commodity-based Trade Model

In the last decade or so, various authors have suggested that commodity-based IO analysis represents a sounder foundation for regional and interregional models than does the institutional approach (see, for example, Hewings & Jensen, 1986). Oosterhaven (1984) has outlined a general accounting framework for rectangular tables for use in interregional models. A few attempts have been made to incorporate commodities within a more general IO modelling framework in concrete empirical analyses (see, for example, Dewhurst & West, 1990; Skoglund, 1980). Greenstreet (1987) has made one of the more comprehensive attempts to move interregional IO modelling into a commodity–industry approach. However, in general, the use of commodity-based tables in the analysis of interregional trade has been limited. Eding and Oosterhaven (1996) have recently again raised the discussion in relation to the modelling of interregional trade flows.

5.1. Models in Structural Form

In Figure 2, the interregional model is instead based on a trade model by commodity. The horizontal dimension has two subdivisions, i.e. place of demand and place of production.

The vertical dimension now has three subdivisions, i.e. sector components, final demand by component, and demand (intermediate and final) by commodity. In the D-W cell, final demand is accounted for. This demand is translated to commodities from cell D-W to cell D-C via a use matrix. Intermediate consumption goes directly from cell A-S to D-C via a use matrix, translating sectoral intermediate demand into commodities. Total demand by commodity in cell D-C is met by (i) imports from abroad, (ii) imports from other regions and (iii) production in the region itself. Imports from other regions are transformed from cell D-C to cell A-C through a model for interregional trade by commodities. In cell A-C, exports to abroad, exports to other regions and sales to the regional market together generate demand for regional production. This total production by commodity is transformed from cell A-C to cell A-S by the make matrix **M**. The circuit then continues as before.

In the following, the model is first described. Then, the construction of model variables based on regional make and use matrices and interregional commodity trade matrices is examined. Finally, the procedures for the construction of the regional make and use matrices, using the national approach, are presented.

5.2. Danish Model in Structural Form

At present, an operational local economic model (LINE) is being developed for (the 275) Danish municipalities (Madsen *et al.*, 1997) in a SAM framework. In LINE, the transformation from sectors to commodities and from components of final demand to commodities is as follows.

Tables 1–3 show the structure and notation of the make, use and commodity

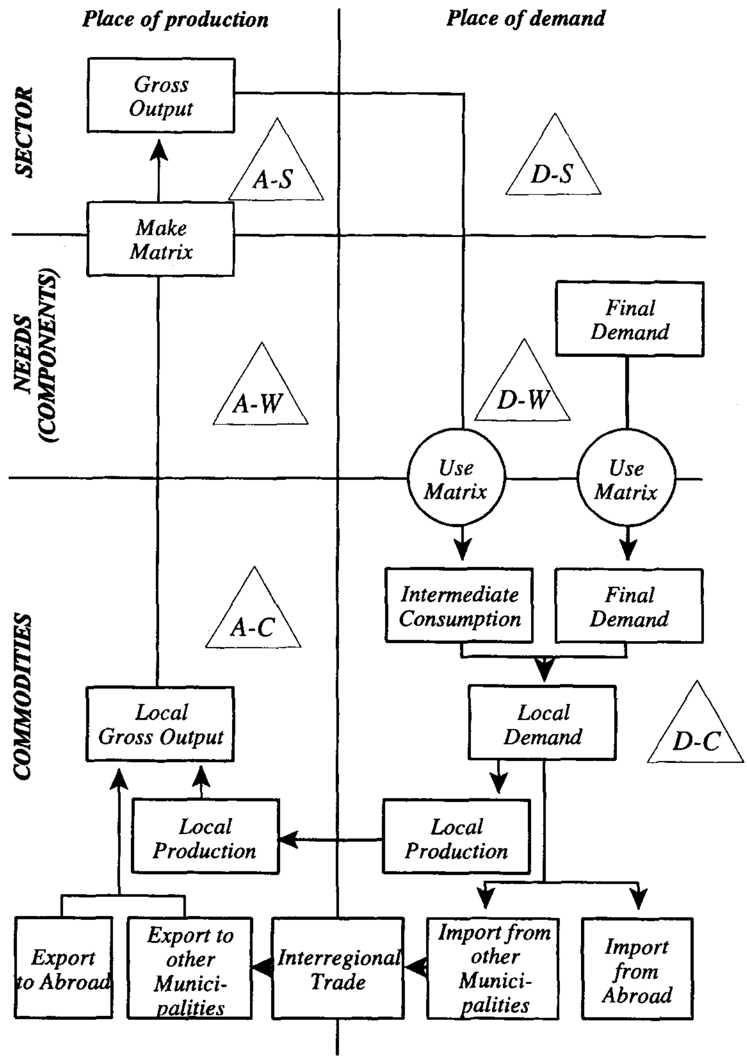

Figure 2. Interregional model based on a make and use approach and trade in commodities.

Table 1. Make matrix by region

		Commodities	Total supply
Local output	By sector	$\mathbf{V}^{R,L}$	$\mathbf{V}_{E}^{R,L}$
	Total	$\mathbf{V}_{V}^{R,L}$	$\mathbf{V}_{V,E}^{R,L}$
Imports from abroad	By country	$\mathbf{V}^{R,F}$	$\mathbf{V}_{W}^{R,F}$
	Total	$\mathbf{V}_{V}^{R,F}$	$\mathbf{V}_{V,W}^{R,F}$
Total supply		$\mathbf{V}_{V}^{R}$	$\mathbf{V}^{R}$

Table 2. Use matrix by region

	Intermediate consumption		Private consumption		Public consumption		Investment		Local demand	Foreign exports		Total demand
Commodities	$\mathbf{U}_{IC}^{S,L}$	$\mathbf{U}_{V,IC}^{S,L}$	$\mathbf{U}_{CP}^{S,L}$	$\mathbf{U}_{V,CP}^{S,L}$	$\mathbf{U}_{CO}^{S,L}$	$\mathbf{U}_{V,CO}^{S,L}$	$\mathbf{U}_{I}^{S,L}$	$\mathbf{U}_{V,I}^{S,L}$	$\mathbf{U}_{V}^{S,L}$	$\mathbf{U}^{S,F}$	$\mathbf{U}_{V}^{S,F}$	$\mathbf{U}_{V}^{S}$
Total demand	$\mathbf{U}_{E,IC}^{S,L}$	$\mathbf{U}_{V,E,IC}^{S,L}$	$\mathbf{U}_{W,CP}^{S,L}$	$\mathbf{U}_{V,W,CP}^{S,L}$	$\mathbf{U}_{W,CO}^{S,L}$	$\mathbf{U}_{V,W,CO}^{S,L}$	$\mathbf{U}_{W,I}^{S,L}$	$\mathbf{U}_{V,W,I}^{S,L}$	$\mathbf{U}^{S,L}$	$\mathbf{U}_{W}^{S,F}$	$\mathbf{U}_{V,W}^{S,F}$	$\mathbf{U}^{S}$

Table 3. Commodity balance and trade

	The region itself	Other regions	Production for the domestic market	Export abroad	Total production
The region itself	[$\mathbf{Z}_V^{R,L} = \mathbf{Z}_V^{S,L}$	$\mathbf{Z}_V^{R,O}$]	$\mathbf{Z}_V^{R,D}$	$\mathbf{Z}_V^{R,F}(=\mathbf{U}_V^{S,F})$	$\mathbf{Z}_V^{R}(=\mathbf{V}_V^{R,L})$
Other regions	[$\mathbf{Z}_V^{S,O}$	$\mathbf{Z}_V^{R,S,O}$]			
Domestic demand	$\mathbf{Z}_V^{S,D}$				
Foreign imports	$\mathbf{Z}_V^{S,F}\ (=\mathbf{V}_V^{R,F})$				
Total demand	$\mathbf{Z}_V^{S}\ (=\mathbf{U}_V^{S,L})$				

[ ]: These four matrices constitute the gross intra and interregional trade matrix $\mathbf{Z}_V^D$

balance and trade matrices used in the model and the data construction procedures. In Tables 1–3 and the following equations, the notation used is as follows.

With regard to matrices, **V** is a make matrix, **U** is a use matrix and **Z** is an interregional trade matrix. The superscripts used are as follows: R denotes region of supply; S denotes region of demand; L denotes a local (regional) origin of supply and demand; O denotes an other-region origin of supply and demand; F denotes foreign origin of supply and demand; D denotes domestic (all domestic regions); and NAT refers to national tables. The subscripts used are as follows: V denotes commodity; E denotes sector; W denotes a component of final demand (or country group); IC denotes intermediate consumption; CP denotes private consumption; CO denotes public consumption; I denotes investment.

In the equations which follow, the use matrix in coefficient form is defined as **B**, the make matrix is **D** and the trade matrix is **T**.

Demand for commodities for intermediate consumption is determined through a use matrix that relates sectoral demand to commodities, i.e.

$$\begin{aligned}\mathbf{U}_{V,IC}^{S,L} &= \mathbf{B}_{IC}^{S,L}\,(\mathbf{U}_{E,IC}^{S,L}) \\ &= \mathbf{B}_{IC}^{S,L}\,(\mathbf{X}^R - \mathbf{H}^R)\end{aligned} \tag{12}$$

where the following notation is used:

- $\mathbf{U}_{V,IC}^{S,L}$ is intermediate consumption by commodity and by place of demand S;
- $\mathbf{B}_{IC}^{S,L}$ is the use matrix for intermediate consumption in coefficient form by place of demand S, which is by definition identical to place of production R;
- $\mathbf{U}_{E,IC}^{S,L}$ is intermediate consumption by sector and by place of demand S/place of production R;
- $\mathbf{X}^R$ is gross output by sector and by place of production R;
- $\mathbf{H}^R$ is GDP at factor cost by sector and by place of production R.

Demand for commodities for private consumption is determined through a use matrix that relates private consumption by component, i.e.

$$\begin{aligned}\mathbf{U}_{V,CP}^{S,L} &= \mathbf{B}_{CP}^{S,L}\,\mathbf{U}_{W,CP}^{S,L} \\ &= \mathbf{B}_{CP}^{S,L}\,\mathbf{CP}^S\end{aligned} \tag{13}$$

where the following notation is used:

- $\mathbf{U}_{V,CP}^{S,L}$ is private consumption by commodity and by place of demand S;

$\mathbf{B}_{CP}^{S,L}$ is the use matrix for private consumption in coefficient form by place of demand S;

$\mathbf{U}_{W,CP}^{S,L}, \mathbf{CP}^{S}$ is private consumption by component and by place of demand S.

Public consumption by component is then transformed into demand for commodities via a use matrix, i.e.

$$\begin{aligned}\mathbf{U}_{V,CO}^{S,L} &= \mathbf{B}_{CO}^{S,L}\,\mathbf{U}_{W,CO}^{S,L} \\ &= \mathbf{B}_{CO}^{S,L}\,\mathbf{CO}^{S}\end{aligned} \tag{14}$$

where the following notation is used:

$\mathbf{U}_{V,CO}^{S,L}$ is public consumption by commodity and by place of demand S;

$\mathbf{B}_{CO}^{S,L}$ is the use matrix for public consumption in coefficient form by place of demand S;

$\mathbf{U}_{W,CO}^{S,L}, \mathbf{CO}^{S}$ is public consumption by component and by place of demand S.

Investment is transformed, by component, into demand for commodities via a use matrix, i.e.

$$\begin{aligned}\mathbf{U}_{V,I}^{S,L} &= \mathbf{B}_{I}^{S,L}\,\mathbf{U}_{W,I}^{S,L} \\ &= \mathbf{B}_{I}^{S,L}\,\mathbf{I}^{S}\end{aligned} \tag{15}$$

where the following notation is used:

$\mathbf{U}_{V,I}^{S,L}$ is investment by commodity and by place of demand S;

$\mathbf{B}_{I}^{S,L}$ is the use matrix for investment in coefficient form by place of demand S;

$\mathbf{U}_{W,I}^{S,L}, \mathbf{I}^{S}$ is investment by component and by place of demand S.

Total local demand is the sum of demand for commodities for intermediate consumption, private consumption, public consumption and investment. We have

$$\mathbf{U}_{V}^{S,L} = \mathbf{U}_{V,IC}^{S,L} + \mathbf{U}_{V,CP}^{S,L} + \mathbf{U}_{V,CO}^{S,L} + \mathbf{U}_{V,I}^{S,L} \tag{16}$$

where $\mathbf{U}_{V}^{S,L}$ denotes total demand by commodity and by place of demand S.

The model treats mobile and immobile commodities differently. A mobile commodity is a geographically transferable commodity, while an immobile commodity is consumed at the place of production (such as in hairdressing).

Local demand for mobile commodities is met by imports from abroad and by domestic production. The demand for domestically produced commodities is determined as

$$\mathbf{Z}_{V}^{S,D} = \mathbf{U}_{V}^{S,L} - \mathbf{Z}_{V}^{S,F} \tag{17}$$

where $\mathbf{Z}_{V}^{S,D}$ is demand for domestic production by commodity and by place of demand S; and $\mathbf{Z}_{V}^{S,F}$ denotes imports from abroad by commodity and by place of demand S.

Imports from abroad are determined by local import share and local demand. We have

$$\mathbf{Z}_{V}^{S,F} = \mathbf{T}_{V}^{S,F}\,\mathbf{U}_{V}^{S,L} \tag{18}$$

where $\mathbf{T}_{V}^{S,F}$ denotes foreign imports as a share of local demand by commodity and by place of demand S.

For mobile commodities, the relation between local demand for domestic production and local supply for domestic demand is

$$\mathbf{Z}_{V}^{R,D} = \mathbf{T}_{V}^{D} \mathbf{Z}_{V}^{S,D} \tag{19}$$

where $\mathbf{Z}_{V}^{R,D}$ denotes gross output sold to the domestic market by commodity and by place of production R; and $\mathbf{T}_{V}^{D}$ is the domestic trade matrix in coefficient form by place of production R and by place of demand S.

Local production of mobile commodities is determined by the sum of local supply for domestic demand and exports to abroad, i.e.

$$\mathbf{V}_{V}^{R,L} = \mathbf{Z}_{V}^{R} = \mathbf{Z}_{V}^{R,D} + \mathbf{Z}_{V}^{R,F} \tag{20a}$$

and local production of immobile commodities is determined by local supply for local demand

$$\mathbf{V}_{V}^{R,L} = \mathbf{Z}_{V}^{R} = \mathbf{Z}_{V}^{R,L} \tag{20b}$$

where $\mathbf{V}_{V}^{R,L}$ and $\mathbf{Z}_{V}^{R}$ denote gross output by commodity and by place of production R; and $\mathbf{Z}_{V}^{R,F}$ denotes exports to abroad by commodity and by place of production R.

Foreign exports are determined by foreign demand and relative export prices.

Total production can then be transformed from production by commodity to production by sector, using a reverse make matrix, i.e.

$$\mathbf{X}^{R} = \mathbf{D}^{R,L} \mathbf{V}_{V}^{R,L} \tag{21}$$

where $\mathbf{D}^{R,L}$ is the make matrix for place of production R.

The analytical solution to this model could be given by the modified Leontief inverse shown already, supplemented by a trade model. The model can also be solved numerically by the round-by-round method.

In addition to the advantages associated with the decomposition of production and demand into use and make processes, there are other, more profound theoretical reasons for developing this approach. In standard production theory, production functions that incorporate intermediate consumption use groups of homogeneous commodities as inputs in the production process (the use matrix); in the theory of joint production, production involves the simultaneous production of a number of different commodities (the make matrix). Demand theory is also based on demand for homogeneous groups of commodities—termed 'components'—which enter the utility function of consumers, before being transformed into specific commodities (the use matrix for final demand).

This interregional commodity–trade model can be expanded with a variety of submodels, depending on the aims of the modelling exercise. For example, a relation between production, income and private consumption can be incorporated using a consumption function, or a labour market model can incorporate employment and unemployment. One important advantage of constructing models in structural form is that account can be taken explicitly of interaction between the commodity–trade module and the other submodels. In the reduced-form model, this type of interaction will usually be modelled at a high level of aggregation, which conceals underlying and more fundamental economic structures. Expansion of the basic model with submodels makes analytical solutions increasingly difficult, as non-linear relations must be combined inside one analytical framework—a problem which is reduced by the use of structural models which are solved numerically.

5.3. Construction of Model Variables

The basis for the construction of data for use with structural interregional IO models is the national make and use matrices combined with regional data on production and demand. This is in contrast to the institutional approach, which bases data construction on national institutional tables using sectoral data.

The regional use relations in the model are derived in terms of data from a regional use table $\mathbf{U}^{S}$. We have

$$\begin{aligned} \mathbf{B}_{IC}^{S,L} &= \mathbf{U}_{IC}^{S,L}(\hat{\mathbf{U}}_{E,IC}^{S,L})^{-1} = \mathbf{U}_{IC}^{S,L}(\hat{\mathbf{X}}^{R} - \hat{\mathbf{H}}^{R})^{-1} \\ \mathbf{B}_{CP}^{S,L} &= \mathbf{U}_{CP}^{S,L}(\hat{\mathbf{U}}_{W,CP}^{S,L})^{-1} \\ \mathbf{B}_{CO}^{S,L} &= \mathbf{U}_{CO}^{S,L}(\hat{\mathbf{U}}_{W,CO}^{S,L})^{-1} \\ \mathbf{B}_{I}^{S,L} &= \mathbf{U}_{I}^{S,L}(\hat{\mathbf{U}}_{W,I}^{S,L})^{-1} \end{aligned} \tag{22}$$

where $\mathbf{U}_{IC}^{S,L}$, $\mathbf{U}_{CP}^{S,L}$, $\mathbf{U}_{CO}^{S,L}$ and $\mathbf{U}_{I}^{S,L}$ are regional use matrices for intermediate consumption, private consumption, public consumption and investment by place of demand. $\hat{\mathbf{U}}_{E,IC}^{S,L}$, $\hat{\mathbf{U}}_{W,CP}^{S,L}$, $\hat{\mathbf{U}}_{W,CO}^{S,L}$ and $\hat{\mathbf{U}}_{W,I}^{S,L}$ are diagonal regional matrices for intermediate consumption by sector, and for private consumption, public consumption and investment by component and by place of demand. These matrices are derived from the regional use matrices summed by column.

The trade relations in the model are derived in terms of data from an interregional and intraregional (domestic) trade matrix $\mathbf{Z}_{V}^{D}$, i.e.

$$\mathbf{T}_{V}^{D} = \mathbf{Z}_{V}^{D}(\hat{\mathbf{Z}}_{V}^{S,D})^{-1} \tag{23}$$

where we have the following notation:

- $\mathbf{T}_{V}^{D}$ is the inter- and intraregional (domestic) trade coefficient matrix by place of production S, by place of demand R and by commodity V;
- $\mathbf{Z}_{V}^{D}$ is the inter- and intraregional (domestic) trade matrix by place of production S, by place of demand R and by commodity V;
- $\hat{\mathbf{Z}}_{V}^{S,D}$ is the diagonal regional matrix for domestic production for regional demand by commodity and by place of demand—this matrix is derived from the inter- and intraregional trade matrix summed by rows.

The make matrix in the model is derived from regional make matrices, i.e.

$$\mathbf{D}^{R,L} = \mathbf{V}^{R,L}(\hat{\mathbf{V}}_{V}^{R,L})^{-1} \tag{24}$$

where $\mathbf{V}^{R,L}$ is the regional make matrix by place of production R; and $\hat{\mathbf{V}}_{V}^{R,L}$ denotes diagonal regional matrices for gross output by commodity and by place of production R. These matrices are derived from the regional make matrix summed by column.

The three data matrices form the basis for the model variables and are related as follows:

$$\mathbf{Z}_{V}^{S,D} = \mathbf{Z}_{V}^{S} - \mathbf{Z}_{V}^{S,F} = \mathbf{U}_{V}^{S,L} - \mathbf{V}_{V}^{R,F} \tag{25a}$$

$$\mathbf{Z}_{V}^{R,D} = \mathbf{Z}_{V}^{R} - \mathbf{Z}_{V}^{R,F} = \mathbf{V}_{V}^{R,L} - \mathbf{U}_{V}^{S,F} \tag{25b}$$

where $\mathbf{V}_{V}^{R,F}$ is the regional make matrix for import from abroad (foreign supply) by place of demand; and $\mathbf{U}_{V}^{S,F}$ is the regional use matrix for foreign exports (foreign demand) by place of production.

5.4. Data Construction using the National Non-survey Approach

There are three basic steps in data construction using the national non-survey approach:

(1) calculation of regional supply and demand;
(2) calculation of interregional and international export and import;
(3) calculation of interregional trade flows.

In each case, the data constructed are by commodity.

In the national approach, the regional use and make matrices are constructed by combining regional data for production and final demand with national use and make matrices ($\mathbf{B}^{NAT}$ and $\mathbf{D}^{NAT}$), together with a special non-survey procedure for estimating inter- and intraregional trade.

Regional supply and demand. The regional use matrix in values for intermediate consumption is derived as follows:

$$\mathbf{U}^{S,L}_{E,IC} = \mathbf{X}^{R} - \mathbf{H}^{R} \tag{26a}$$

$$\mathbf{U}^{S,L}_{IC} = \mathbf{B}^{NAT}_{IC}\,\hat{\mathbf{U}}^{S,L}_{E,IC} \tag{26b}$$

For private consumption (and, in a similar manner, for public consumption and investment), the regional use matrix is derived as follows:

$$\mathbf{U}^{S,L}_{W,CP} = \mathbf{CP}^{S} \tag{27a}$$

$$\mathbf{U}^{S,L}_{CP} = \mathbf{B}^{NAT}_{CP}\,\hat{\mathbf{U}}^{S,L}_{W,CP} \tag{27b}$$

Similarly, the regional make matrix is derived as follows:

$$\mathbf{V}^{R,L}_{E} = \mathbf{X}^{R} \tag{28a}$$

$$\mathbf{V}^{R,L} = \mathbf{D}^{NAT}\,\hat{\mathbf{V}}^{R,L}_{E} \tag{28b}$$

Interregional and international export and import. Having derived the use and make matrices, the next step is to obtain the reduced trade matrix ($\mathbf{Z}$) (as shown in Table 3). In this trade matrix, the commodity balance constrains implicitly the data construction procedure and, at the same time, a number of elements from the make and use matrices are included. The following identity, which requires supply to equal demand by commodity (row sum equals column sum), holds for each region:

$$\mathbf{Z}^{R}_{V} + \mathbf{Z}^{S,O}_{V} + \mathbf{Z}^{S,F}_{V} = \mathbf{Z}^{S}_{V} + \mathbf{Z}^{R,O}_{V} + \mathbf{Z}^{R,F}_{V} \tag{29}$$

The next step is to estimate the values in the individual $\mathbf{Z}$ matrices. In order to undertake this, it is necessary to extend the make and use matrices with information on foreign exports and imports. The procedures used are described next and the transfer of these data to the trade matrices is presented.

Foreign exports are derived from the national use and make matrices and the regional gross output. National foreign export shares by commodity are derived as

$$\mathbf{B}^{F,NAT} = \mathbf{U}^{F,NAT}(\hat{\mathbf{V}}^{NAT}_{V})^{-1} \tag{30}$$

where we have the following notation:

- $\mathbf{B}^{F,NAT}$ is the national export (F) share by commodity and by destination country;
- $\mathbf{U}^{F,NAT}$ is the national use matrix for foreign exports in values by commodity and by destination country;
- $\hat{\mathbf{V}}_{V}^{NAT}$ is a diagonal matrix of national production by commodity.

Local foreign exports are derived by multiplying gross output by commodity, with these national foreign export shares. We have

$$\mathbf{U}^{S,F} = (\hat{\mathbf{V}}^{R,L})\,\mathbf{B}^{F,NAT} \tag{31}$$

where $\mathbf{U}^{S,F}$ is the regional use matrix for foreign exports in values by commodity, by destination and by place of production S.

Total export by commodity is derived by aggregating over destinations, i.e.

$$\mathbf{Z}^{R,F} = \mathbf{U}_{V}^{S,F}\,\mathbf{i} \tag{32}$$

where $\mathbf{i}$ denotes the column summation vector, i.e. $(1, \ldots, 1)'$.

National import shares by commodity are derived as

$$\mathbf{D}^{F,NAT} = \mathbf{V}^{F,NAT}\,(\hat{\mathbf{U}}_{V}^{NAT})^{-1} \tag{33}$$

where $\mathbf{D}^{F,NAT}$ is the national import (F) share by commodity and by country of origin; and $\mathbf{V}^{F,NAT}$ is the national make matrix for foreign imports in values by commodity and by country of origin.

Local foreign imports are derived by multiplying local demand by commodity, with these national foreign import shares. We have

$$\mathbf{V}^{S,F} = \mathbf{D}^{F,NAT}\,(\hat{\mathbf{U}}_{V}^{S,L}) \tag{34}$$

where $\mathbf{V}^{S,F}$ is the regional make matrix for foreign imports in values by commodity, by country of origin and by place of demand R.

Total import by commodity is derived by aggregating over countries of origin:

$$\mathbf{Z}^{S,F} = \mathbf{i}'\,\mathbf{V}_{V}^{S,F} \tag{35}$$

The following data are carried forward from the regional make and use matrices, and the residual supply for the domestic market and the residual demand for commodities produced domestically arc determined as

$$\begin{aligned}
\mathbf{Z}_{V}^{R} &= \mathbf{V}_{V}^{R,L} \\
\mathbf{Z}_{V}^{R,F} &= \mathbf{U}_{V}^{S,F} \\
\mathbf{Z}_{V}^{R,D} &= \mathbf{V}_{V}^{R,L} - \mathbf{U}_{V}^{S,F} \\
\mathbf{Z}_{V}^{S} &= \mathbf{U}_{V}^{S,L} \\
\mathbf{Z}_{V}^{S,F} &= \mathbf{V}_{V}^{R,F} \\
\mathbf{Z}_{V}^{S,D} &= \mathbf{U}^{S,L} - \mathbf{V}_{V}^{R,F}
\end{aligned} \tag{36}$$

Local production going to domestic markets is divided between local consumption ($\mathbf{Z}_{V}^{R,L}$) and interregional exports ($\mathbf{Z}_{V}^{R,O}$), and local demand supplied from domestic production is divided between local production ($\mathbf{Z}_{V}^{S,L}$) and interregional imports ($\mathbf{Z}_{V}^{S,O}$). These elements are calculated in different ways, depending on whether local production for domestic markets is greater or less than local demand for domestic production:

If $\mathbf{Z}_V^{R,D} \geqslant \mathbf{Z}_V^{S,D}$, then

$$\mathbf{Z}_V^{S,O} = 0$$

$$\mathbf{Z}_V^{R,L} = \mathbf{Z}_V^{S,D}$$

$$\mathbf{Z}_V^{R,O} = \mathbf{Z}_V^{R,D} - \mathbf{Z}_V^{S,D}$$

If $\mathbf{Z}_V^{R,D} < \mathbf{Z}_V^{S,D}$, then

$$\mathbf{Z}_V^{R,O} = 0$$

$$\mathbf{Z}_V^{R,L} = \mathbf{Z}_V^{R,D} \quad (37)$$

$$\mathbf{Z}_V^{S,O} = \mathbf{Z}_V^{S,D} - \mathbf{Z}_V^{R,D}$$

In the first case, where local supply for the domestic market is greater than local demand from the domestic market, then interregional imports are set equal to zero, local production for the local market is set equal to local demand for domestic production, and interregional export is set equal to excess supply of local production for the domestic market. In the second case, where local demand from the domestic market is greater than local supply to the domestic market, interregional exports are set equal to zero, local production for the local market is set equal to local supply for the domestic market, and interregional import is set equal to excess local demand for domestic products.

Finally, adjustments can be made for cross-hauling, where interregional imports are, as a point of departure, set to at least 10% of local demand. A discussion of determination of cross-hauling shares is to be found in Section 6.

If $\mathbf{Z}_V^{R,D} \geqslant \mathbf{Z}_V^{S,D}$, then

$$\mathbf{Z}_V^{S,O} = 0.1\,\mathbf{Z}_V^{S,D}$$

$$\mathbf{Z}_V^{R,L} = 0.9\,\mathbf{Z}_V^{S,D}$$

$$\mathbf{Z}_V^{R,O} = \mathbf{Z}_V^{R,D} - 0.9\,\mathbf{Z}_V^{S,D}$$

If $\mathbf{Z}_V^{R,D} < \mathbf{Z}_V^{S,D}$, then

$$\mathbf{Z}_V^{R,O} = 0.1\,\mathbf{Z}_V^{R,D}$$

$$\mathbf{Z}_V^{R,L} = 0.9\,\mathbf{Z}_V^{R,D} \quad (38)$$

$$\mathbf{Z}_V^{S,O} = \mathbf{Z}_V^{S,D} - 0.9\,\mathbf{Z}_V^{R,D}$$

Interregional trade flows. The final step involves the calculation of interregional trade flows, using the calculated totals for interregional exports and imports by region and by commodity, i.e. $\mathbf{Z}_V^{R,O}$ and $\mathbf{Z}_V^{S,O}$ for each region.

There are alternative approaches available. One approach is to employ entropy-maximizing procedures, including, as a special case, the linear programming solution

$$Z^{\mathrm{O}}_{\mathrm{V},i,j} = A_i B_j Z^{\mathrm{R,O}}_{\mathrm{V},i}\, Z^{\mathrm{S,O}}_{\mathrm{V},j} \exp(-\beta_{\mathrm{V}} c_{\mathrm{V}ij}) \tag{39}$$

where

$$A_i = \left[\sum_j B_j Z^{\mathrm{S,O}}_{\mathrm{V},j} \exp(-\beta_{\mathrm{V}} c_{\mathrm{V}ij}) \right]^{-1}$$

$$B_j = \left[\sum_i A_i Z^{\mathrm{R,O}}_{\mathrm{V},i} \exp(-\beta_{\mathrm{V}} c_{\mathrm{V}ij}) \right]^{-1}$$

Another alternative is to employ a solution based on a model of monopolistic competition (see, for example, Treyz & Bumgardner, 1996).

5.5. Data Construction using the Survey Approach

It is possible to improve the national non-survey approach through the use of the survey approach. In relation to each of the three steps outlined already, the following improvements are possible.

Regional supply and demand. In this step, survey methods can replace the national make and use coefficients. As will be argued in the following section, this is perhaps a less worthwhile exercise.

Interregional and international export and import and interregional trade flows. A survey approach would almost certainly integrate these two steps, collecting data on export destinations. These data can be used to test assumptions about national export shares and the distribution of production destined for the domestic market by own-region consumption and interregional export. Survey data can then be used to test the accuracy of the trade flow distribution model.

In the survey approach, international imports appear as a residual. This can be seen in equation (29). Here, the first step is to estimate gross output by commodity. Using survey information on destination of sales, local demand, interregional exports and international exports are calculated. Then, on the basis of interregional exports by destination, interregional imports by region of origin are determined implicitly. International imports remain as a residual. By comparison, in the national non-survey approach, interregional exports and imports appear as the residual.

6. Data Validity, Consistency and Practical Considerations when using the National Non-survey Approach

In this section, the theoretical validity of the national approach is examined. Evaluation of validity is based on the assumption that data are estimated at the highest possible level of disaggregation, both in spatial and sectoral terms. Using the principle of disaggregation under restrictions of internal data consistency (which is the same as using the national non-survey approach based on make and use matrices), it can be concluded, in general, that data quality is high and is also better than that of institutional approaches that employ non-survey methods. This is also the case for the estimation of trade flows.

Table 4. Estimates of data quality—the national approach

Variable	Absolute magnitude	Relative uncertainty in the regional variable	Relative uncertainty in make and use matrix	Absolute level of uncertainty	Source
Supply					
$\mathbf{V}_{V}^{R,L}$ Gross output in the region	Large or zero	$\mathbf{V}_{E}^{R,L}$ low	$\mathbf{D}^{NAT}$ moderate	Moderate or zero[a]	Statistics Denmark
$\mathbf{Z}_{V}^{S,O}$ Interregional imports	Small	—	—	Low	Own estimation
$\mathbf{Z}_{V}^{S,F}$ Foreign imports	Small	$\mathbf{U}_{V}^{S,L}$ low	$\mathbf{D}^{F,NAT}$ moderate	Low	Statistics Denmark and own estimation
Demand					
$\mathbf{U}_{V,IC}^{S,L}$ Intermediate consumption	Medium or zero	$\mathbf{U}_{E,IC}^{S,L}$ low	$\mathbf{B}_{IC}^{NAT}$ moderate	Moderate or zero[a]	Statistics Denmark
$\mathbf{U}_{V,CP}^{S,L}$ Private consumption	Small	$\mathbf{U}_{W,CP}^{S,L}$ low	$\mathbf{B}_{CP}^{NAT}$ moderate	Low	Statistics Denmark and own estimation
$\mathbf{U}_{V,CO}^{S,L}$ Public consumption	Small	$\mathbf{U}_{W,CO}^{S,L}$ low	$\mathbf{B}_{CO}^{NAT}$ low	Low	Statistics Denmark
$\mathbf{U}_{V,I}^{S,L}$ Investments	Small	$\mathbf{U}_{W,I}^{S,L}$ low	$\mathbf{B}_{I}^{NAT}$ moderate	Low	Statistics Denmark
$\mathbf{Z}_{V}^{R,O}$ Interregional exports	Large or zero	—	—	Moderate or zero[a,b]	Own estimation
$\mathbf{Z}_{V}^{R,F}$ Foreign exports	Large or zero	$\mathbf{V}_{E}^{R,L}$ low	$\mathbf{D}^{F,NAT}$ moderate	Moderate or zero[a,b]	Statistics Denmark

Notes: [a]The level of uncertainty related to these estimates depends on whether or not production takes place in the region. [b]The absolute level of uncertainty for these two components together is low, but the absolute level of uncertainty of each is either moderate or zero.

6.1. Data Validity: Theoretical Considerations

There are two stages in the assessment of data quality. First, the quality of the data entering into the components of supply and demand by region is examined. Secondly, the data quality of the residual components in the procedure for the calculation of the commodity balance is evaluated. The point of departure is the commodity balance represented in equation (29), and assessments of data quality are presented in Table 4.

Data can be subdivided into three different quality groups:

- The first group includes only gross output by sector ($\mathbf{V}_{E}^{R,L}$) and national make data ($\mathbf{D}^{NAT}$). These data are of high quality, because the source is primary data from Statistics Denmark.
- The second group is local demand for commodities, including intermediate

consumption by sector and the components of final demand by component. These data are calculated using high-quality data on intermediate consumption ($\mathbf{U}_{E,IC}^{S,L}$) and final demand ($\mathbf{U}_{W,CP}^{S,L}, \mathbf{U}_{W,CO}^{S,L}, \mathbf{U}_{W,I}^{S,L}$), and national use data ($\mathbf{B}_{IC}^{NAT}, \mathbf{B}_{CP}^{NAT}, \mathbf{B}_{CO}^{NAT}, \mathbf{B}_{I}^{NAT}$). There is, of course, an issue here: the extent to which national use data can be used at the regional level. By using the principle of disaggregation in a small country, this assumption is not unreasonable.

- The third group is imports from and exports to abroad ($\mathbf{Z}_{V}^{R,F}, \mathbf{Z}_{V}^{S,F}$), which are calculated using national import and export shares ($\mathbf{D}^{F,NAT}$ and $\mathbf{B}^{F,NAT}$), and combined with data on demand and production by commodity and by municipality. Again, because Denmark is a small country and the level of disaggregation is high, the assumption of national commodity-based import and export shares is not unreasonable. However, clearly, they rest on weaker assumptions than those of the second group.

Finally, the quality of the residual components in the commodity balance is clearly the weakest element. Their quality would seem to depend on the quality of the three groups just described. However, this is not correct, for the following reason. If data are constructed on a very detailed spatial and sectoral level, then Table 4 indicates levels of uncertainty associated with the residual components, ($\mathbf{Z}_{V}^{RO}, \mathbf{Z}_{V}^{SO}$). Two cases are examined: either production is present in the region or it is not. The problem of uncertainty is centred on interregional imports and exports, and uncertainty depends on whether or not production of the commodity in question actually occurs in the region. If production does not take place, then uncertainty related to interregional exports is zero and uncertainty related to interregional imports (for demand) is low, because demand is certain. If production does take place, then uncertainty is concentrated on both the commodity composition of production (the make matrix) and exports. Where production exists, total exports, including foreign exports, have a low uncertainty, while distribution for foreign and interregional exports is more uncertain. The low uncertainty for total exports arises because (a) gross output is certain, (b) imports from abroad are certain in absolute terms (as they are small), (c) intermediate consumption is medium and (d) the absolute level of uncertainty for final demand is low, because final demand is low.

The conclusion is that net interregional trade flows are estimated with a reasonable degree of validity. There remains the problem of assessing to what extent interregional exports and imports considered independently are valid. By assuming any given level of cross-hauling, consistency can be achieved (see equation (38)). This means that little can be said of this type of validity *a priori*. However, the principle of applying a high level of disaggregation, both in terms of commodity and geography, reduces the problem somewhat. The limiting case is where commodities and geography are infinitely finely divided, in which case no cross-hauling occurs. In reality, the magnitude and nature of cross-hauling must be determined empirically. In addition, the cross-hauling problem only arises for mobile commodities, as discussed in Section 5.2 (equations (20a) and (20b)).

6.2 Data Consistency

In the national approach, the local trade data are constructed using a top-down approach. Therefore, the local data for production, final demand and trade will add up to the corresponding data in the national accounts.

Using survey data to estimate the destination of exports, the data quality for trade improves. However, the data are no longer, by definition, consistent with national data. For example, the sum of local foreign exports by commodity will not necessarily add up to the national export. Whether or not the trade data eventually should be scaled to the national level to fulfil the requirements of consistency depends on what the data should be used for.

6.3 Practical Considerations

The national non-survey approach requires the following data:

- national make and use matrices;
- regional data on gross output by sector;
- regional data on intermediate consumption by sector;
- regional data on final demand by component;
- interregional transport costs.

The institutional approach requires the same data, except that the national institutional IO table is used instead of the national make and use matrices. In many countries, institutional IO tables are constructed on the basis of make and use tables, following the UN system, which means that there is, in principle, no problem of data availability. Thus, there seem to be no practical data-related reasons why methods which are theoretically better founded cannot be used.

7. Conclusions

Commodity-based interregional IO analysis has a sounder theoretical foundation than does sector-based analysis, because there is a closer relationship to the underlying theory of production and consumption. This is especially relevant in the case of trade theory, because trade is with commodities rather than the output of sectors. Models in structural rather than reduced form are conceptually more straightforward, are easier to expand and develop and, as has been shown, are as easy to assemble using non-survey methods as institutional models. When using non-survey methods, the make and use approach builds more directly on national-level supply and use data, which are collected in a commodity-based framework. Careful use of regional-level data incorporating national make and use matrices, applied at the interregional level, can help to develop estimates of interregional trade flows. A principal conclusion is that, if data are constructed at a high level of spatial and sectoral disaggregation, then their validity will generally be good. In practical terms, the only real difference between the data requirements for the two approaches is the demands made on the form of the national IO tables. Because make and use tables form the basis for national institutional tables in most countries, there are no data-related reasons why the make–use approach cannot be developed. The reasons for the prevalence of institutional frameworks of analysis seem to relate to conceptual elegance and, perhaps, a conceptual lock-in.

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Main Section D:

Regional Consequences of Transportation Investments and Regulation

Section 11:

Modelling the Regional Economic Effects of the Danish Great Belt Link

Chris Jensen-Butler and Bjarne Madsen

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MODELLING THE REGIONAL ECONOMIC EFFECTS OF THE DANISH GREAT BELT LINK

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ABSTRACT Different approaches to modelling the impact of transport infrastructure investment on regional economic development are examined, including production function and economic potential approaches. An integrated modelling approach involving both transport costs and models of regional and interregional economic structure is advocated. This approach is applied to the question of forecasting the regional economic effects of the Danish Great Belt link, a major Danish infrastructure investment, due to open in 1997. These effects are shown to be modest.

1. INTRODUCTION

Interest in the regional economic effects of major transport infrastructure investments has been growing in recent years, not least because of the increasing size of such investments. Examples include studies on the Channel Tunnel, the Öresund link between Denmark and Sweden and the TGV Paris-Lyon. Simultaneously, interest in development of techniques to model the relationship between transport infrastructure investment and regional economic development has grown. A central theme has been to identify changes in regional competitiveness through infrastructure investment, particularly transport infrastructure. The present paper presents an approach to this problem which was developed in a concrete analytical context, that of forecasting the regional economic effects of the opening of the Danish Great Belt link in 1997, and of related traffic infrastructure improvements. The main theme of the paper is, however, primarily the modelling approach used. Initial results will only be presented in brief.

2. MODELLING THE IMPACT OF TRANSPORT INFRASTRUCTURE INVESTMENT ON REGIONAL ECONOMIC DEVELOPMENT: DIFFERENT APPROACHES

Interest in the relationship between transport infrastructure and regional economic development within a policy framework (e.g. Blonk 1979; Biehl, 1986; Björner et al., 1993) has existed for some years, and transport infrastructure is one of the key areas identified by the European Union to promote development in lagging regions and greater efficiency for Europe as a whole as well as greater social cohesion. (See CEC 1992a, 1992b, and Bruinsma and Rietveld, 1993)

Numerous transport infrastructure projects have been examined in terms of their contribution to regional economic growth, for example, in the case of motorways (Dodgson 1973, Bruinsima et al 1993), airports (Van den Berg and Van der Meer 1991), high-speed trains (TGV) (Bonnafous 1987) and bridges (Simon 1987). Large-scale infrastructure investments in recent years have provoked a number of more extensive studies of which the Channel Tunnel is among the better known (Vickerman and Flowerdew 1990, Vickerman 1987, Holliday, Marcou and Vickerman 1991, Marcial Echenique and Partners (1991)).

The concept of infrastructure is rather slippery. Johansson and Karlsson (1994) define infrastructure as a factor stimulating growth and development, influencing accessibility and factor mobility, thereby improving allocative efficiency. It also influences both input and marketing costs, reduces costs associated with economic networks and promotes formation of innovative networks. More specifically, they define infrastructure as:

(a) Capital with fixed location

(b) Providing services with a fixed spatial extension (which can be regarded as a positive externality)

(c) Providing benefits subject to distance decay

(d) Providing services which are polyvalent (i.e. different subjects and actors can benefit), which can be used repeatedly over time and which provide a system coordination function.

It is clear that transport infrastructure possesses all of these attributes. In their analysis of infrastructure in the Swedish Mälar region they provide a rich set of variables to describe regional infrastructure, including many transport-related variables which represent network quality and accessibility. The present study utilizes a much simpler infrastructure concept, where user costs are taken as the measure of infrastructure quality. Clearly, further refinements are possible along the lines of the Mälar study.

A number of different approaches to modelling these relationships are now emerging which have been described by a number of authors, including Rietveld (1992), Rietveld and Nijkamp (1993) and Bruinsima, Rietveld and Nijkamp (1991). These authors distinguish between micro- and macro-level studies.

Micro-level studies are usually based at the level of the firm and involve interviews and questionnaires and can be incorporated within a demand modelling framework, using either stated or revealed preference models. An ex-ante stated preference approach has been used by Illeris and Jacobsen (1991) with Danish firms, in an attempt to evaluate potential effects of the opening of the Great Belt link. Simon (1987) provides an example of an ex-post analysis of the effects of the opening of the Humber bridge in the UK and Bonnafous

(1987) provides interview-based results concerning the effect of the TGV on regional economies along the Paris-Lyon axis. As Rietveld (1992) points out, the approach is problematic for a number of reasons, including lack of precision, bounded rationality of respondents and incomplete knowledge. It also tends to ignore the indirect effects on other firms. A general result of this type of approach seems to be that the effects of transport infrastructure investment are limited. Some model-based studies incorporate more qualitative questionnaire-based approaches into their general analytical framework (ACT et al 1992).

At the aggregate level three principal approaches can be identified: the production function approach, the transport cost approach and the accessibility approach.

The production function approach (see for example, Johansson (1993), Rietveld (1989)) involves the formulation of a production function for a sector in a region, where transport infrastructure enters the function as an independent supply-side element:

$$Y_{ir} = f_{ir}(L_{ir}, K_{ir}, TI_r, OI_r)$$

where:

Y_{ir} = Value added in sector i in region r

L_{ir} = Employment in sector i in region r

K_{ir} = Stock of private capital in sector i and region r

TI_r = Transport infrastructure in region r

OI_r = Other infrastructure in region r

The production function approach has been used almost exclusively for ex-post analyses of the regional economic effects of infrastructure investment, usually based upon historical data.

Bruinsima et al (1991) provide a list of studies made in Europe and Japan from 1970 onwards using this type of approach. Most use a Cobb-Douglas production function, implying a high level of substitutability between inputs. Johansson & Mattson (1993) provide data on infrastructure elasticities from a number of recent American studies.

The effects of transport infrastructure investment can be assessed by examining the output elasticities of the infrastructure inputs. In Aschauer's (1989) study, dealing with infrastructure in general, rather than specifically transport related infrastructure, he found a high coefficient of 0.39 for US data, while lower coefficients have been identified for specifically transport infrastructure investments, such as those listed by Johansson & Mattson (1993). The American Federal Highway Administration places more credibility on these lower coefficients, which tend to bunch in the range 0.15-0.25.

Seitz (1993) has developed the production function approach to include the dual cost function associated with the production function, in order to assess cost savings associated with public infrastructure provision in the field of transport

The transport cost approach involves assessment of changes in regional competitiveness based upon changes in transport costs for both goods and people between spatial units. Changes in trade and travel patterns are modelled, as relative transport costs between regions change. Furthermore, regional levels of activity also change as the overall transport costs change. This will affect economic activity related to both interregional and international exports. These macro effects are obtained using price elasticity models. Furthermore, effects of changing transport flows can also be related to changes in economic activity in the transport sector itself. Plassard (1977) presents some examples of this type of approach, and the present authors have used a transport cost approach within an integrated framework, outlined below (Madsen & Jensen-Butler, 1992).

The accessibility analysis approach is typically based upon an aggregate measure of accessibility for each zone in a zonal system in a pre-investment situation. To this end potential models have often been used:

$$P_i = \sum_{j=1}^{n} (E_j \cdot c_{ij}^{-b})$$

where:

P_i = Economic potential in zone i

E_j = Employment in zone j

c_{ij} = Transport cost from zone i to zone j

b = Parameter

The appropriate interzonal c_{ij} values are then altered as a consequence of the provision of new transport infrastructure and the new accessibility measures are calculated for each zone. Then follows the rather difficult exercise of relating change in potential value to changes in regional income and employment. Examples of this type of approach are provided by Jensen-Butler and Madsen (1995) in the case of the three fixed links of the Western Baltic and by Evers et al (1987) who use this type of model to evaluate the effects of the proposed high-speed rail (TGV) link from Brussels to Amsterdam and Hamburg. Their model involves more terms than the simple potential model described above, having an international border dummy term, a modal split parameter and an employment at risk parameter (i.e. the part of employment in each sector which can potentially be affected by the TGV).

A weakness of this type of accessibility approach is that it tends to regard change in accessibility from the viewpoint of the single node, rather than with respect to the consequences for the network as a whole, perhaps underestimating the positive externalities associated with improvements in transport infrastructure.

In general, the production function approach seems to suggest greater regional economic effects of transport infrastructure investment than the accessibility modelling approach.

3. INTEGRATED APPROACHES

The effects of transport infrastructure provision on regional competitiveness can be incorporated within a unified modelling framework involving both changes in transport costs, and models of regional and interregional structure. The advantage of this approach is that changes in transport flows can be related to changes in regional economic activity in an interactive manner. An example of this type of approach is provided by Amano & Fujita (1970), where changes in transport costs are related to changes in coefficients in an interregional input-output model, to derive outputs in terms of income, population and employment, which are again fed into the input-output model. Sasaki et el (1987) utilize a similar approach, incorporating differences in input prices as well as transport cost. In Europe a similar approach has been adopted by Marcial Echenique & Partners (1992), based upon integrated regional economic models (input-output models) and traffic models; detailed specification of the models is not available. The model has been applied to the Channel Tunnel, where the results indicated rather limited regional economic effects, greatest for regions close to the tunnel and for regions with large export sectors. The effects on industry are generally less than for service. It is within this tradition of integrated modelling that the Great Belt model has been developed.

In comparison with the production function approach, input-output based approaches have usually been applied to ex-ante situations, as a calibrated model is employed, using fixed parameters, where different exogenous variable assumptions are used to drive the model.

4. MODELLING THE EFFECTS OF THE GREAT BELT LINK

The Great Belt Link

Figure 1 shows the location of the link, and as can be seen, it will be a new central element in the Danish space-economy, linking the two halves of the country having 2.3 million inhabitants to the east and 2.7 million to the west. Figure 1 also shows the location of the Danish counties (regions) as well as three larger regions used in the analysis. Today, traffic across the Great Belt is served by car and rail ferries. There are, in addition, a number of other ferry routes between Zealand and Jutland and 10 domestic airline routes, all with frequent services. In 1991 9.8 million passengers crossed the Great Belt, of which about 4 million travelled by train; there were 2.2 million air travellers between east and west Denmark in 1990 and 5.8 million tons of freight were transported by road and 2 million tons by rail between east and west Denmark in 1991 (Trafikministeriet, 1993). 2.4 million cars crossed the Great Belt in 1991, which can be compared with the 1.6 million cars registered in Denmark (AIS, 1992). The principal ferry routes other than those over the Great Belt are also shown in Figure 1.

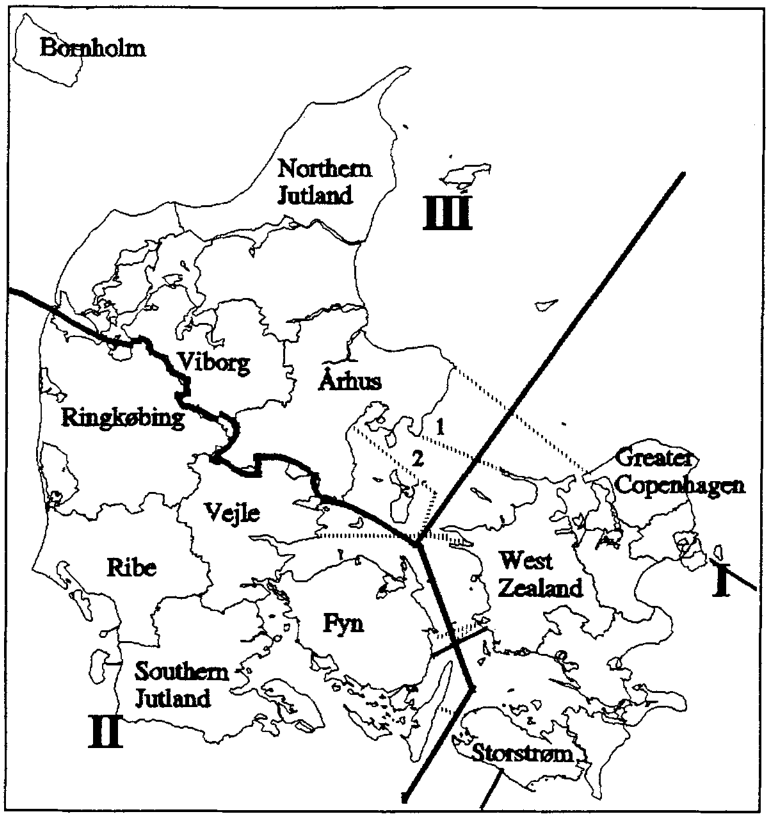

FIGURE 1. Danish counties, three larger regions (I-III), the Great Belt Link and principal ferry routes. Route 1 is Ebeltoft-Odden and route 2 Kalundborg-Aarhus.

The fixed link will be a combined road and rail link, and changes in travel times will be substantial after the opening of the link and the completion of associated improvements to rail services and to the motorway network. These associated improvements consist basically of the implementation of high-speed trains (180km/hour) and building of new motorways—to northern Jutland, to Esbjerg in the west and filling gaps in the existing network. Travel times between Copenhagen and Odense (Fyn) will be reduced from 3 hours by train and ferry to 1.25 hours by train. Between Copenhagen and Aarhus the reduction will be from 4.25 hours to 2.5 hours. Travel times by road will also be affected markedly: between Copenhagen and Odense travel time will be almost halved and between Copenhagen and Aarhus, the reduction will be about 33%. In the modelling exercise described below, cost savings for travel between some regions are as high as 60% for service related transport, whilst freight cost reductions for industrial products are substantially less, up to 13%. This is because savings in wages and salaries play a greater role in service production than is the case for industrial (and agricultural) production.

The complexity of the Great Belt situation has, however, increased, as the plans for construction of two other fixed links, between Denmark and Sweden over the Öresund, and between Denmark and Germany over the Fehmarn belt, have developed. These other two infrastructure investments have not yet been incorporated inside this modelling framework.

The Great Belt link will be opened in 1997 and the present modelling exercise attempts to identify the regional economic consequences of this link.

Modelling The Regional Economic Effects Of The Link

Regional economic effects of such investment can be considered in three stages:

(a) The initial effects associated with the period of construction, where the multiplicative effects of large scale infrastructure investment on regional economies is of interest.

(b) The short and medium term effects of the opening of the link on production, employment and incomes by region, including changes in patterns of interregional trade.

(c) The long-term dynamic effects of the opening of the link on such questions as location of production, commuting patterns, labor market structure, industrial organization, logistics etc.

Stage 1 can be analyzed using standard regional input-output techniques, whilst Stage 3 is very difficult indeed to model, but should probably be tackled using the production function approach. Stage 2 is the main concern of the present modelling exercise.

The modelling approach deals only with the production and transport of goods and services in Danish regions. Three stages of model development were initially envisaged. First, modelling the distributive effects on interregional flows between regions of the opening of the fixed link. Second, modelling the growth effects in different regions in Denmark of changing levels of regional exports. Third, modelling the growth effects on regions of changes in international exports. At present only stages one and two have been developed.

Stage 1: Distributional Effects

Here the aim is to model changing patterns of interregional trade, assuming constant interregional exports and imports by sector and region. The core of the modelling exercise is the development of an interregional input-output model, AIDA. This model was developed at the Local Governments' Research Institute in Copenhagen (AKF) and is described in Madsen (1991a).

The model was built up from 12 single region models for 12 Danish regions named EMIL (see Madsen 1991b). These single region models were constructed using non-survey techniques; theoretical and methodological inputs to these models have been provided by earlier work on regional models in Denmark (Groes 1982, Holm 1984) and by work undertaken in Portugal (Gaspar, Abreu, Ferrão & Jensen-Butler, 1989).

Ex-post tests of the performance of the single region models indicate that they are reasonably accurate. Likewise, comparison with recent data on GDP at factor cost by sector and by region collected by the Danish Statistical Office, suggests that the models are reliable.

AIDA is a Keynesian income multiplier model which incorporates as its central element an interregional input-output model for 12 Danish regions. The basic structure of the model is shown in Figure 2. The input-output model which lies at the core of AIDA is an interregional model having 12 regions:

Greater Copenhagen	Vestsjælland
Storstrøm	Bornholm
Fyn	Sønderjylland
Ribe	Vejle
Ringkøbing	Århus
Viborg	Nordjylland

and 6 production sectors:

Agriculture	Industry
Building & Construction	Private Service
Transport service (including telecommunications)	Public service

These six sectors are aggregated from 21 sectors (also used in EMIL)Seven categories of final demand, aggregated from 18 categories, are used in the model:

Private consumption	Public consumption
Investment (machines etc.)	Investment (buildings, etc.)
Stocks	Export (international)
Imputed financial services.	

In AIDA private consumption is treated endogenously in the framework of a Keynesian multiplier model. The remaining 6 categories of final demand are thus the motor which drives the model. The resulting GDP at factor cost by sector and region is translated by a lengthy process into disposable income in each region which in turn generates increases in private consumption via non-linear (national) consumption functions, which are fed back into the model to generate a new (but smaller) round of income increase. An iterative procedure—the Gauss Seidel method—is used to solve the sets of equations. The advantage of this procedure (as opposed to the standard procedure of rendering private consumption and wages endogenous by inclusion in the basic transactions matrix) is that non-linear consumption functions can be used.

Twelve matrices of technical coefficients together with the final demand coefficients have been estimated for the input-output component of each of the 12 single-region models, using non-survey methods. The 12 regional input-output technical coefficient matrices appear on the principal diagonal of the interregional model (see Figure 3). For each single region table, the technical coefficients matrix and the final demand coefficients matrix for each single region model, together with exports destined for other Danish regions and imports from other Danish regions, have been estimated as follows.

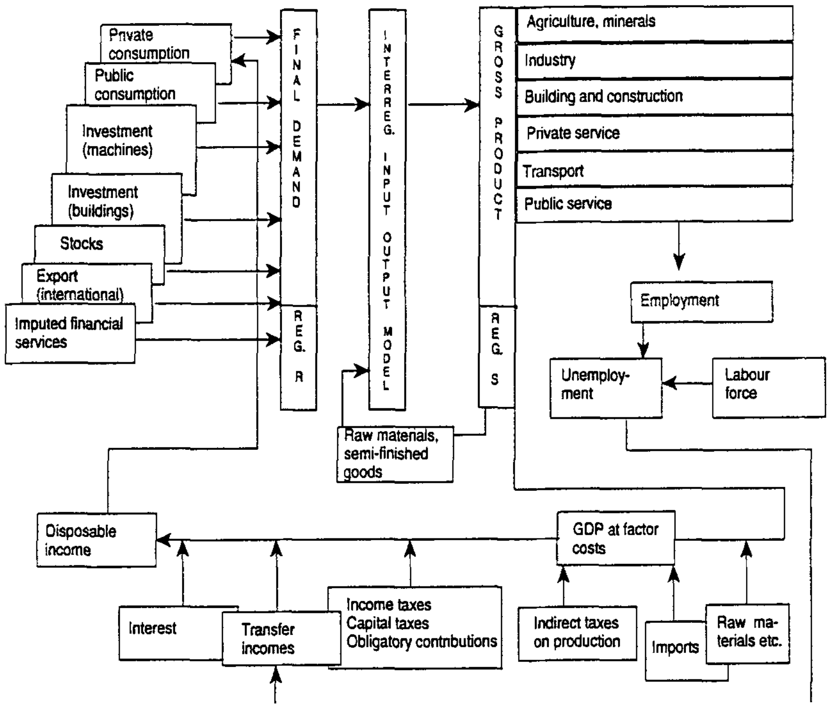

FIGURE 2. The structure of AIDA

To / From	Intermediate products Region					Final demand Region				
	1	2	3	...	12	1	2	3	...	12
Region 1	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	...	$A_{1,12}$	$F_{1,1}$	$F_{1,2}$	$F_{1,3}$	...	$F_{1,12}$
Region 2	$A_{2,1}$	$A_{2,2}$	$A_{2,3}$	...	$A_{2,12}$	$F_{2,1}$	$F_{2,2}$	$F_{2,3}$	...	$F_{2,12}$
Region 3	$A_{3,1}$	$A_{3,2}$	$A_{3,3}$	...	$A_{3,12}$	$F_{3,1}$	$F_{3,2}$	$F_{3,3}$	...	$F_{3,12}$
Region 12	$A_{12,1}$	$A_{12,2}$	$A_{12,3}$	...	$A_{12,12}$	$F_{12,1}$	$F_{12,2}$	$F_{12,3}$	...	$F_{12,12}$
Import from abroad by sector of origin	M_1	M_2	M_3	...	M_{12}	U_1	U_2	U_3	...	U_{12}
Other imports	NM_1	NM_2	NM_3	...	NM_{12}	NU_1	NU_2	NU_3	...	NU_{12}
Other primary inputs	Y_1	Y_2	Y_3	...	Y_{12}	Z_1	Z_2	Z_3	...	Z_{12}
Gross product/ Final demand	X_1	X_2	X_3	...	X_{12}	E_1	E_2	E_3	...	E_{12}

FIGURE 3. The basic interregional input-output table in AIDA. (Capital letters represent individual matrices which are a part of the general table.)

Estimates of Gross Product by sector and region were made during the earlier EMIL modelling exercise (Madsen 1991b). The sales from one sector for intermediate consumption in the region were then estimated by first calculating the value of the regional technical coefficients and then converting these to flows in money terms. The regional technical coefficients were estimated using standard non-survey techniques based upon use of the Location Quotient (LQ) for each sector (see, for example, Hewings, 1970). Using this method the national technical coefficients are adjusted if LQ is < 1, otherwise the national technical coefficients are used:

$$a^R_{i1i2} = n_{i1i2} \cdot LQ_{i1} \text{ if } LQ_{i1} < 1.0$$

otherwise

$$a^R_{i1i2} = n_{i1i2}$$

where:

a^R_{i1i2} :Technical coefficient for two sectors, $i1$ and $i2$ in region R

n_{i1i2} :Technical coefficient for two sectors at national level

Gross product by sector and region is used as the basis for the calculation of Location Quotients.

The final demand coefficients have been calculated in a similar manner, though the Cross Industry Coefficient (Hewings 1970) has been used instead of the Location Quotient. Both sets of coefficients are then transformed into monetary flows and subtracted from the Gross Product. The resulting residual is the export potential of that region in that sector for export to other Danish regions. This is shown in the following:

$$IRE^R_{i1} = FX^R_{i1} - \sum_{i2} a^R_{i1i2} \cdot FX^R_{i2} - \sum_j f^R_{i1j} \cdot FC^R_j$$

where:

IRE^R_{i1} = Export potential in region R in sector $i1$

FX^R_{i1} = Value of Gross product in sector $i1$ in region R

FC_j = Component j of final demand

a^R_{i1i2} = Technical coefficient for the two sectors in region R

f^R_{i1j} = Final demand coefficient linking sector $i1$ with component j of final demand.

Interregional imports, both for intermediate consumption and for final demand, appear during the coefficient estimation process and are transformed into import flows in money terms as follows:

$$IRM^R_{i1} = \sum_{i2}(1 - a^R_{i1i2}) \cdot FX^R_{i2} + \sum_j(1 - f^R_{i1j}) \cdot FC^R_j$$

where:

IRM_{i1}^{R} =Import requirements in region R in sector $i1$

In addition, a 10% cross-hauling constraint has been imposed, which augments interregional trade. The choice of 10% is somewhat arbitrary, as is the use of 10% over all sectors. The choice of 10% is related to an earlier empirical investigation of trade flows in one Danish region, suggesting that non-survey methods tend to overestimate intra-regional trade by this order of magnitude (Korsgaard 1985).

Thus, interregional export potential is calculated as a residual, and import requirements are calculated by summing all components of import when calculating the value of input coefficients and converting these to money terms. Whilst for any one sector in any one region imports and exports will not usually be equal, by definition:

$$\sum_{R} IRE_{i1}^{R} = \sum_{S} IRM_{i1}^{S} \text{ for each } i1$$

where:

R = is the exporting region and S is the importing region.

The next problem is to estimate the interregional trade flows and calculate the interregional trade coefficients, given the ε port potential of each sector in each region and import requirements for both intermediate and final consumption by sector of origin. For this purpose entropy maximizing methods have been used in the form of the double constrained spatial interaction model:

$$EXIM_{i1}^{RS} = A_R B_S IRE_{i1}^{R} IRM^{S}{}_{i1} \, f(c_{i1}^{RS})$$

where:

$EXIM_{i1}^{RS}$=trade flow from region i to region j for a given sector

$f(c_{i1}^{RS})$= generalized cost function for sector $i1$

A_R and B_S are defined as follows:

$$A_R = (\sum_{S} B_S IRM_{i1}^{S} f(c_{i1}^{RS}))^{-1}$$

$$B_S = (\sum_{R} A_R IRE_{i1}^{R} f(c_{ij}))^{-1}$$

In order to operationalise this part of the overall model a matrix of interregional generalized costs is needed; this is discussed below. In addition, as no full O-D matrix for freight or passenger travel exists in Denmark, independent choice of the parameters of the generalized cost function has to be made. In AIDA an exponential function is used:

$$f(c_{i1}^{RS}) = e^{(-\beta c_{i1}^{RS})}$$

The value chosen for β (0.05) is derived from other studies applying this type of entropy formulation.

AIDA operates at a high level of sectoral aggregation. However, interregional export and import has been calculated at the level of 21 individual sectors; afterwards, the gross flows obtained from this analysis with 21 sectors have been aggregated to 6 sectors.

AIDA provides endogenous estimates of a large number of key regional economic variables, including: Gross Product by sector, GDP at factor cost by sector, employment by sector, unemployment, disposable income, taxes and tax base, transfer incomes, private consumption by sector, interregional export and import by sector.

Ex-post evaluation has been made to examine the performance of the model when compared with published data. The model performs very satisfactorily in estimating basic regional macro-economic variables. For example, over a number of years it can predict sectoral/regional employment and gross output in most cases within 0-3% of the actual value (Madsen 1991a). However, the ability of the model to replicate interregional flows of goods and services is at present difficult, if not impossible, to evaluate. This is partly because there is a lack of suitable data, even with respect to the ferry links, but mainly because the flows derived from the model are value flows and there is no easy solution to the problem of translating such flows into physical (transport) flows. Such an exercise would also require a high level of sectoral disaggregation, which is difficult to apply in a multi-regional approach involving 12 regions.

After the model was operationalised using a 12 x 12 generalized cost matrix for the situation before the opening of the fixed link, a new generalized cost matrix was calculated incorporating the changes in transport costs arising from the opening of the fixed link and related transport infrastructure improvements. The distributional effects were modelled by retaining the same vectors of total interregional export and total interregional import for each region and sector in the second run of the model.

Stage 2: Growth Effects

Here the aim is to model changes in income and employment by sector and by region as a consequence of changes in transport costs created by the Great Belt link. Increased accessibility will, in general, improve a region's competitive ability. Decreases in transport costs will translate into declining prices, which allows us to use export price elasticities to calculate increases in interregional exports:

$$E_{X,P} = \frac{(dx)}{x} \Big/ \frac{(dp)}{p}$$

where:

x = sales volume

p = price

There are no Danish data available on the sensitivity of interregional exports to regional price and transport cost change. However, in recent years a number of studies have appeared on Danish exports' dependence on wage costs and price changes for specific categories of exports. In general, the elasticities are estimated to be 1 - 2.5, depending, amongst other things, upon the sector in question. In this study, the national elasticities have been applied. Two main reservations can be made concerning this approach. First, the regional export price elasticities may be greater than the national elasticities as regional markets are more flexible and homogenous than the national market. Second, market imperfections may appear more frequently in regional markets than in international markets which implies regional import elasticities which are lower than the national ones.

When calculating the effects of cost reductions three elements must be included:

(a) Transport costs' share of total costs

(b) Interregional transport costs' share of total transport costs

(c) Percentage change in transport costs.

These elements are combined as follows:

$$dX = (E_{x,p} - 1)q_{tr}q_{trir}d_{tr}$$

where:

dX = changes in interregional export (per cent)

$E_{x,p}$ = export price elasticity

q_{tr} = transport costs' share of total costs

q_{trir} = interregional transport costs' share of total transport costs

d_{tr} = per cent change in transport costs

Due to lack of data, broad assumptions concerning these elements have been made. For all sectors it is assumed that $E_{x,p} = 2.0$, $q_{tr} = 6\ \%$ and $q_{trir} = 50\ \%$. Further work will permit the use of more differentiated and accurate values. Increases in interregional exports by sector and by region have been calculated. As the sum of interregional imports must equal the sum of exports, growth in regional imports has been distributed by region in relation to the sectoral regional gross output. This rests on the assumption that gross output reflects total demand.

Once these direct macro effects have been estimated, AIDA then proceeds to estimate the indirect and induced effects on both regional GDP and employment, by sector.

4.3 Operationalising The Model: Transport Costs

Estimation of interregional transport costs is described briefly below. The calculations are laborious and have been undertaken for both freight and passenger travel. All calculations assume that ferries will disappear from the Great Belt, as the main parameter of competition is time cost in the Great Belt area and there is little scope for retaliatory action by the one small private ferry company operating there. The State Railway Company (DSB) dominates the ferry market in the Great Belt and these routes will be closed. Further away, it is generally accepted that one or two Kattegat ferries will survive: very probably Ebeltoft-Odden ((1) in Figure 1) and possibly Kalundborg-Århus ((2) in Figure 1), because of accessibility to North and Mid Jutland. One unknown factor is how many catamaran ferries will operate in the Kattegat, being a new transport technology, it is rather difficult to model.

Freight

For freight, the cost calculation is based upon 4 transport types: Lorry, trailer, rail wagon and combi, transport costs being calculated for 8 groups of merchandise. These are reduced to two in AIDA (agriculture and industry). For each type of product, costs for each of the four transport types are calculated using the following elements: distance-dependent costs, time-dependent costs, ferry ticket costs, freight-specific costs and start and reloading costs.

Transport costs can be calculated on the principle of least cost route or the actual transport pattern. A more sophisticated version of the model will allow for a distribution of trips by mode and route, rather than the all-or-nothing solution adopted here. Because of the complicated geography of Denmark such an improvement is very demanding indeed in terms of data, as interregional trips across the Great Belt always involve combinations of several modes. A large number of zones is used, and in this analysis the cheapest route principle is used. The costs involved with each type of transport have been weighted, summed and centers of gravity for each region identified. This cost calculation is used for two of the six sectors of AIDA—agriculture, where transport costs for corn and fertilizers form the basis of the calculation, and for industrial products, where transport costs for four of the remaining seven groups of merchandise are utilized.

The procedure is then repeated for the improved transport net with the fixed link. As noted above, it is assumed that two ferry routes will survive: Ebeltoft-Odden and Århus-Kalundborg. Table 1 shows an example of percentage changes in costs for transport of industrial products between regions. In general, cost savings are limited, with the highest values reaching 12.5%. This is because the only real cost advantage for freight is time savings when actually crossing the Great Belt, as motorway improvements will only increase time savings marginally. Cost savings are greatest for regions closest to the link.

Passenger transport

For passenger transport five different transport types are considered: Car, train, ferry, bus and airplane. The elements of transport cost which can enter into the generalized costs are total travel time, direct transport costs, distance, frequency and comfort.

TABLE 1. Calculated % change in generalised transport costs between 12 Danish regions for industrial products after the opening of the Great Belt link[a]

From/ to region	1	2	3	4	5	6	7	8	9	10	11	12
1	0.0	0.0	0.0	0.0	-10.9	-8.4	-8.9	-9.4	-4.9	0.4	-0.2	-0.5
2	0.0	0.0	0.0	0.0	-12.5	-9.2	-9.9	-10.5	-6.8	-0.2	-1.6	-1.2
3	0.0	0.0	0.0	0.0	-11.6	-8.7	-9.3	-9.9	-8.2	-0.0	-4.9	-1.2
4	0.0	0.0	0.0	0.0	-7.5	-6.0	-6.4	-6.6	-3.6	0.2	-0.1	-0.4
5	-11.0	-12.5	-11.6	-7.4	0.0	-6.7	-0.1	0.0	-6.7	0.0	0.0	-7.8
6	-8.4	-9.2	-8.7	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	-8.9	-9.9	-9.3	-6.4	-6.7	0.0	0.0	-10.9	0.0	-11.8	0.0	0.0
8	-9.4	-10.5	-9.9	-6.6	-0.1	0.0	-10.9	0.0	0.0	-10.8	0.0	-9.9
9	-4.9	-6.8	-8.2	-3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.3	-0.2	-0.0	0.2	-6.8	0.0	-11.0	-10.8	0.0	0.0	0.0	-9.4
11	-0.2	-1.6	-5.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	-0.5	-1.2	-1.0	-0.4	-7.8	0.0	0.0	-9.9	0.0	-9.4	0.0	0.0

a. Note: The regions are as follows:

1	Greater Copenhagen	2	Vestsjælland
3	Storstrøm	4	Bornholm
	GREAT BELT		
5	Fyn	6	Sønderjylland
7	Ribe	8	Vejle
9	Ringkøbing	10	Århus
11	Viborg	12	Nordjylland

In the model transport costs are calculated under the assumption that passengers choose the route which minimizes the generalized transport costs. The minimum cost route calculation—both for cars and lorries—is based on a weighted sum of distance and time. As with freight transport, improvements concerning modal and route choice will be introduced.

The final cost matrix is a weighted average of all transport types using centers of gravity for each of the twelve zones. This exercise is then repeated after transport system improvements are included. As with freight, it is assumed that all ferry routes are closed except for Århus-Kalundborg and Ebeltoft-Odden. This type of cost calculation is utilized for the remaining four sectors in the AIDA model: Private service, Building and Construction, Transport services and Public service, as the main product being transported is service embodied in passengers. Here the cost savings are more considerable (up to 60%) as time savings arise not only over the Great Belt but also on the high speed trains.

International transport

The model does not yet include analysis of the consequences of the opening of the Great Belt link for traffic having origins or destinations (or both) outside Denmark. The data requirements are formidable, but work on this problem is in progress. It is further complicated by the synergy effects arising from the construction of a link between Copenhagen and Sweden across the Öresund and the link between Denmark and Germany across the Fehmarn belt. (See Knotka et al 1994.)

5. RESULTS

The main aim of the present paper has been to present the methodology applied in this study; initial results have been obtained from the model (see Madsen & Jensen-Butler 1992) and some examples of general trends are presented in this section.

5.1 Distributional Effects

In order to ease interpretation of the results, which are based upon 12 regions, three large regions have been created by aggregation (see Figure 1). Region 1 is east of the Great Belt, including Greater Copenhagen, Region 2 is west of the Great Belt, including Fyn and Southern Jutland and Region 3 is west of the Great Belt, including mid- and northern Jutland. These aggregations can be seen in Table 2, which shows an example of the distributional changes in trade flows for private service. The figures in the table show changes in flows of value in million kroner (1988 prices), also expressed as a percentage of value flows before the opening of the link. By way of comparison, Danish GDP at factor cost in 1988 was 609 billion kroner. Here it can be seen that the general effect is that Region 1 (Greater Copenhagen and all regions east of the Great Belt) and Region 2 (Fyn and Southern Jutland) increase their interregional trade, whilst the north of Jutland becomes more isolated. This is a general trend which can be found in all six sectors used in the model.

TABLE 2. Changes in international trade flows for private service on a three-region basis.[a]

From/to region	Region 1	Region 2	Region 3
Region 1	-8 (-0.1)	157 (1.0)	-149 (-2.1)
Region 2	239 (8.3)	48 (5.6)	-287 (-38.6)
Region 3	-231 (-14.4)	-206 (-32.3)	436 (27.3)

a. Million Kroner, 1988 prices. The Figures in parentheses are percentage changes in flows as compared with the situation before the opening of the Great Belt link. Three regions are shown in Figure 1.

5.2 Generation Effects

Here the effect of increased interregional exports in the entire system, due to decreasing transport costs, are examined. Table 3 shows the results for private service, in percentage terms only. Region 1 expands its trade with regions 2 and 3 at the expense of trade between Regions 2 and 3 and intra-regional trade. In absolute terms, the increases in flows from Region 1 are larger than any of the other increases. This can be interpreted as increasing dominance of Greater Copenhagen in the market for private service in Denmark, as a consequence of the opening of the link. For industry and agriculture the generative effects are much more modest (between -0.2% and 0.6%), as savings in transport costs play a smaller role in these sectors. Gains are also much more evenly distributed both in percentage and in absolute terms.

TABLE 3. Changes in interregional trade flows for private service arising from changes in the total amounts of interregional trade generated via the export price elasticity mechanism, after the opening of the Great Belt link.[a]

From/to region	Region 1	Region 2	Region 3
Region 1	0.4	0.7	1.6
Region 2	2.6	-4.0	-3.1
Region 3	4.2	-2.6	-1.9

a. Figures are percentage changes in flows as compared with the situation before the opening of the Great Belt link.

5.3 Combined Effects

The two effects can be combined by simple addition. However, as the distributional effect dominates the generative effect, the total pattern of change is closer to the change in distribution of flows rather than the generation-induced flows. The general conclusion is therefore, that Greater Copenhagen and Zealand on the one side, and Fyn/Southern Jutland on the other, will experience increasing interregional trade, whilst mid- and north Jutland will tend to become more isolated and self-centered. This represents a change in relation to the structure of the Danish space economy today, where the Great Belt is a major factor structuring the organization of enterprises and logistics.

5.4 Total Effects

AIDA has calculated the direct, indirect and induced effects of these changes. Table 4 shows the total estimated effects on employment by region as a result of the opening of the Great Belt link. As the table shows, the effects seem to be very modest, both in absolute and relative terms.

TABLE 4. Estimated direct, indirect and induced employment effects arising from the opening of the Great Belt Link and related transport infrastructure improvements, by region

	Changes in employment	Total employment 1991
Copenhagen	1,200	847,924
Vestsjælland	0	116,279
Storstrøm	50	101,335
Bornholm	0	20,936
Fyn	300	199,784
Sønderrjylland	50	111,330
Ribe	150	105,513
Velje	100	153,408
Ringkøbing	50	131,467
Århus	200	276,333
Viborg	0	107,172
Nordjylland	100	211,486
Total	2,200	2,382,966

5.5 Sensitivity Analyses

Further work will involve sensitivity analyses in relation to the parameters, β, q_{tr} and q_{trir}. In addition, different assumption concerning the survival of ferry routes could enter into such a sensitivity analysis.

6. CONCLUSIONS

The integrated approach to modelling the effects of transport infrastructure improvements has been illustrated in the paper, where an interregional input-output model has been linked with an entropy-maximizing transport model to derive regional economic effects, including indirect and induced effects. Various types of model improvement are possible, including the incorporation of international exports into the model and also the effects of changing levels of activity in the transport sector itself. The initial results seem to indicate that the regional economic effects of the opening of the Great Belt link will be modest, and that the two more central regions in Denmark will tend to trade more with each other, whilst northern Jutland will become more isolated. The distributional effects on patterns of trade flows will be substantially greater than the generative effects in terms of trade flows. The main regional economic effect of distributional changes will work through changes in the transport sector in each region.

These predicted modest effects are in accord with findings on the regional economic impact of the Channel Tunnel (Vickerman, 1987, Vickerman and Flowerdew, 1990, Button, 1994), which also indicate that the closest regions will benefit most, supporting the distance decay and neighborhood principles identified by Johansson and Karlsson (1994). Simon(1987), likewise, shows limited effects of the English Humber bridge, though Cambridge Economic Consultants (1987) have calculated more positive employment effects (30,000 new jobs over 18 years) for the Severn Bridge in western England. On the other hand, two bridges constructed adjacent to European capital cities, Lisbon and Istanbul, seem to have created very strong growth effects in an urban context (Montanari 1991, Gaspar and Jensen-Butler 1992). It is in this light that some of the predicted major growth effects for the new Öresund bridge between Denmark and Sweden should be seen (Andersson and Matthiessen, 1993). As physical infrastructure affects most the regions which are closest, then the economic effects will be greatest in those regions adjacent to the infrastructure where the density of population and economic activity is high, which is not the case with the two regions on either side of the Great Belt.

Finally, the model in its present form cannot predict long-term changes in economic activity, including location and organizational structures, which are supply-side induced. This type of change can, of course, be incorporated using scenarios with the model, but other tools must be developed to solve this kind of problem.

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Section 12:

An Eclectic Methodology for Assessment of the Regional Economic Effects of the Femern Belt Link Between Scandinavia and Germany

Chris Jensen-Butler & Bjarne Madsen

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An Eclectic Methodology for Assessment of the Regional Economic Effects of the Femern Belt Link Between Scandinavia and Germany

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JENSEN-BUTLER C. and MADSEN B. (1999) An eclectic methodology for assessment of the regional economic effects of the Femern belt link between Scandinavia and Germany, *Reg. Studies* 33, 751–768. The paper describes a theoretically eclectic methodology developed for assessment of the regional economic effects of the proposed fixed link between Denmark and Germany, across the Femern Belt. The methodology is compared with alternative modelling frameworks. Estimates of the regional economic effects of this fixed link are presented, including evaluation of the synergy effects of this link seen in relation to two other fixed links in the Western Baltic. The short and medium term regional economic effects of this infrastructure investment appear to be limited and perhaps greater in regions somewhat more distant from the link.

Transport infrastructure   Regional economic effects   Synergy effects   Evaluation models

JENSEN-BUTLER C. et MADSEN B. (1999) Une méthodologie éclectique pour évaluer les retombées économiques régionales du Chenal de Femern qui va relier la Scandinavie et l'Allemagne, *Reg. Studies* 33, 751–768. Cet article présente une méthodologie théoriquement éclectique qui a été développée afin de permettre une évaluation des retombées économiques régionales de la liaison fixe qui va relier le Danemark et l'Allemagne à travers le Chenal de Femern. La méthodologie se voit comparer à d'autres structures de modélisation. On présente des estimations des retombées économiques régionales de cette liaison fixe, y compris une évaluation de la synergie de cette liaison par rapport à deux autres liaisons fixes situées dans la Baltique occidentale. Il semble que les retombées économiques régionales à moyen terme de cet investissement sont limitées et sont d'autant plus importantes que les régions sont plus éloignées de la liaison.

Equipement de transport
Retombées économiques régionales   Synergie
Modèles d'évaluation

JENSEN-BUTLER C. und MADSEN B. (1999) Eine eklektische Methodik zur Einschätzung regionalwirtschaftlicher Auswirkungen der Fehmarn Beltverbindung zwischen Skandinavien und Deutschland, *Reg. Studies* 33, 751–768. Dieser Aufsatz beschreibt eine theoretisch eklektische Methodik, die zur Einschätzung der regionalwirtschaftlichen Auswirkungen der geplanten festen Verbindung zwischen Dänemark und Deutschland über den Fehmarn Belt entwickelt worden ist. Die Methodik wird mit alternativen Rahmenmodellen verglichen. Es werden Schätzungen der regionalwirtschaftlichen Auswirkungen dieser festen Verbindung vorgelegt, einschließlich der Bewertung synergetischer Wirkungen dieser Verbindung in bezug auf zwei andere feste Verbindungen in der westlichen Ostsee. Die mittelfristigen regionalwirtschaftlichen Auswirkungen dieser infrastrukturellen Investierung scheinen begrenzt zu sein, jedoch möglicherweise größer in Gebieten, die weiter von der Verbindung entfernt liegen.

Transportinfrastruktur
Regionalwirtschaftliche Auswirkungen
Synergische Wirkungen   Bewertungsmodelle

INTRODUCTION

Denmark is at present the location of three major transport infrastructure investments – fixed links across straits. These fixed links are each 15–20 km in length and represent major investments at the European scale. They also include substantial on-land investments involving motorway access and rail network improvements as well as the possibility of establishing dedicated high-speed rail links. Fig. 1 shows the location of these three projects.

The Great Belt link connects east and west Denmark. It opened for rail traffic in 1997 and for road traffic in 1998. Several *ex ante* evaluations of the regional eco-

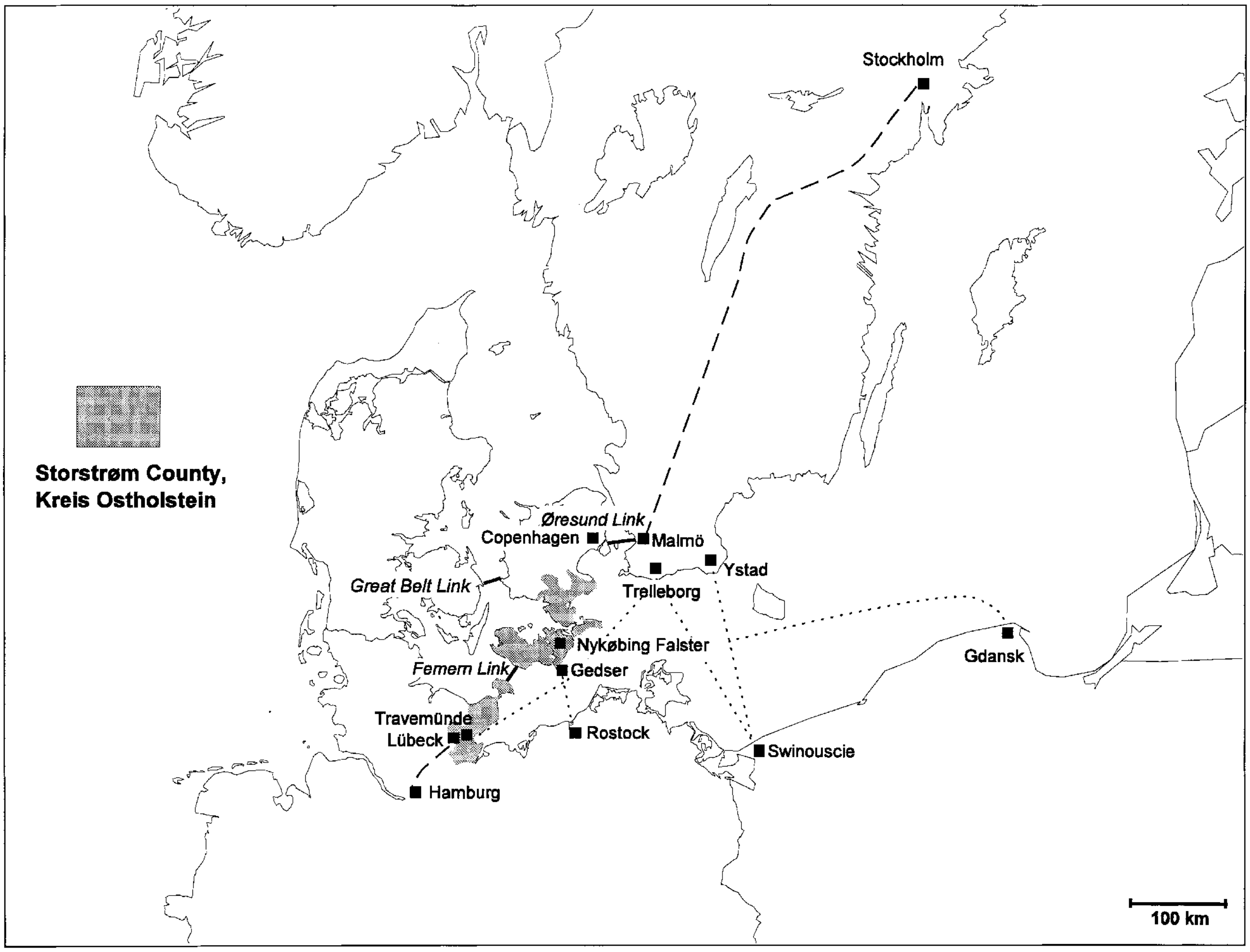

Fig. 1. Three fixed links in the western Baltic

Notes: Storstrøm County (Denmark) and Kreis Ostholstein (Germany) are shaded areas. The trace of the possible high-speed rail link Hamburg-Stockholm is shown as well as the principal ferry routes south of Denmark and Sweden.

nomic effects of this link have been undertaken (ILLERIS and JAKOBSEN, 1991; MADSEN and JENSEN-BUTLER, 1992; JENSEN-BUTLER and MADSEN, 1996a). The Øresund link between Denmark and Sweden also links the cities of Copenhagen and Malmö. Construction has commenced on this link, which will open in 2000. Finally, firm proposals have been made to construct a fixed link across the 20 km wide Femern Belt between Denmark and Germany. These proposals have not yet been finalized or agreed upon and, in addition, the option of building a high-speed rail link from Hamburg to Copenhagen over the Femern Belt and possibly further into Sweden remains open.

Evaluation of the regional economic effects of the Femern link is the principal concern of this paper. However, as is apparent from Fig. 1, the construction of this link, seen in relation to the other two links, has spatial implications which are much wider than those which relate to the relatively limited area of eastern Denmark and Schleswig-Holstein in northern Germany. The three links together open new routes for rail and road traffic in northwestern continental Europe.

In the following, the potential regional economic effects of these transport system improvements, with specific reference to the Femern link, are examined. In the next section the main features of the Femern link are outlined. In the third section, the economies of the two regions adjacent to the link, Storstrøm County in Denmark and Kreis Ostholstein in Germany, are described. In the fourth section, a range of central methods for evaluation of regional economic consequences of transport infrastructure investment is examined and an ideal modelling approach and methodology is outlined. In section five the methodology actually used in this study is described in some detail, including its relation to the approaches described in the previous section, and the principal results are presented. For various reasons, mainly related to data availability, substantial deviations from the ideal modelling methodology had to be adopted, resulting in the development of a more eclectic modelling approach, involving the use of complementary and overlapping theoretical models and methodologies. Finally, general conclusions are drawn both concerning the probable regional economic effects of the link and the adequacy of the methodology employed.

THE FEMERN LINK

The proposed Femern link is a fixed link across the Femern Belt between Denmark and Germany and associated improvements in the rail network. A number of alternative transport technologies are under consideration for the link. The present study deals with the two main alternatives: either a rail-only tunnel, carrying vehicles on a rail shuttle, or a multimodal bridge, combining both rail and road transport. In addition, there are two main rail alternatives: (1) construction of a dedicated high speed rail line (HST), with speeds of over 200 km/h between Hamburg and Copenhagen and with a possible connection to Malmö and even to Stockholm; and (2) upgraded intercity (IC) services with a maximum speed of 180 km/h, using conventional track between Hamburg and Copenhagen. Possible stops between Copenhagen and Hamburg for trains of either type are Nykøbing Falster in Denmark (20 km north of Gedsar) and Oldenburg and Lübeck in Germany. These stops are shown in Fig. 1 which also shows the two regions immediately adjacent to the fixed link, Storstrøm County in Denmark and Kreis Ostholstein in Germany.

The Femern corridor is today used primarily by long distance traffic. Only 17·6% of passengers travelling southwards from Storstrøm county have Kreis Ostholstein or Lübeck as their destination and only 11·7% of passengers from Lübeck or Kreis Ostholstein travelling north have Storstrøm county as their destination (CNOTKA *et al.*, 1994, pp. 332–33). The low level of interaction between the two regions reflects in part the transport barrier, and in part the effect of an international border. The sea constitutes a major transport barrier, both because it involves slower, more costly transport and also the difficulty of a shift between transport modes. The Femern Belt traffic corridor is only one among several corridors linking the Scandinavian countries with Europe south of the Baltic, having at present 33% of car traffic and 12% of lorry traffic from Scandinavia to Europe. The other routes include: (1) the land border between Denmark and Germany in Jutland (38% of car and 66% of lorry traffic from Scandinavia); (2) ferry routes direct from southern Sweden (13% of car and 17% of lorry traffic) as well as less important ferry routes including: (3) from eastern Storstrøm (Gedser) to Rostock in Germany; (4) ferries from the Danish island of Fynen and direct routes from: (5) western Sweden and Norway; and (6) from Finland. These shares can be seen in the first column of Table 3. The reasons for the difference in market shares for cars and lorries are related partly to regulations concerning compulsory rest periods for lorry drivers which can be met on the long-distance ferries from Sweden. In addition, most car journeys are shorter and therefore more local, so that there is not usually a realistic route alternative, even though a ferry crossing constitutes a larger share of time costs for car users as compared with lorries because the car trips are in general much shorter. For cars, the Femern link is used for trips mainly between eastern Denmark (especially Greater Copenhagen) and Schleswig-Holstein, where alternative routes would be more costly.

The Femern link is, however, only one of three major transport infrastructure projects, as described above. The effects of the Femern link cannot, therefore, be examined in isolation, as synergy effects arise from interaction with the other two projects. In the following analysis, in order to isolate the pure effects of the Femern link and related investments in relation to the total effects of all three links, analyses have been undertaken for: (1) the effects on traffic of the two fixed links across the Great Belt and the Øresund without the Femern link; and (2) the combined effects of all three links. The effect of the Femern link is considered to be the difference between the two. Inclusion of measurement of this synergy effect is a feature of the present study.

Travel costs

Generalized transport costs have been used at different stages of the analysis and a brief description of their calculation, which was a major data preparation exercise in the project, follows. For 222 locations in Europe, generalized inter-zonal transport cost matrices were obtained or calculated for six transport modes: three types of car (small, medium, large), lorries, rail and air. These 222 destinations were then reduced to a smaller number of zones for further analysis (180 zones in one case and 100 zones in another).

For the four road transport modes the following expression was used to calculate generalized transport costs:

$$go_{ij}^{TM} = act^{TM} \cdot tt_{ij}^{TM} + acl^{TM} \cdot tl_{ij}^{TM} + tp_{ij}^{TM}$$

where:

go_{ij}^{TM} = generalized cost of travelling from zone i to zone j using transport mode TM
act^{TM} = average cost per minute travelling time using mode TM
tt_{ij}^{TM} = travelling time using mode TM between i and j
acl^{TM} = average cost per kilometre using transport mode TM
tl_{ij}^{TM} = trip length between i and j using mode TM
tp_{ij}^{TM} = ticket price for using ferry or fixed link travelling from zone i to j using mode TM

The distance, time and economic data on road trips between all destinations were obtained from a British route scheduling system *Auto Route Plus*, designed for company car and lorry fleet scheduling in Europe; it is a system which permits user specification of a number of parameters. The route scheduling system also takes into account speeds on six different categories of road, the mix of which depends upon the route chosen. However, the system's treatment of ferry links was completely replaced by more accurate and sensitive calculation procedures. For a medium sized car, the cost per km is 0·2 ECU and for a lorry 0·135 ECU. Average costs per minute travelling time were 0·45 ECU for a medium sized car and 0·14 ECU for a lorry. Finally, the system was adapted to provide data for each of seven transport corridors identified between Scandinavia and Europe.

For rail and air transport, data on generalized transport costs between destinations were calculated from data provided by a major Danish consultancy firm, Hoff & Overgaard, who have prepared origin–destination matrices for 130 zones in Europe for passenger traffic by rail, air (and car, though this was not used in the present study) for Danish public authorities. The data were adapted and extended to the 180-zone framework employed in this study. The data set also contains information on ticket prices and travel times between the zones. Generalized transport costs were derived from this data using a combination of ticket costs and time costs. The cost of travel time for rail was set to 0·45 ECU per minute and ticket costs 0·25 ECU per km for HST, compared with about 0·1 ECU for IC in the original data.

The effects of the Femern link on generalized transport costs for travel between the two regions, for travel from each of the two regions to destinations outside the regions and for traffic passing through the regions illustrate some of the potential changes. For car travel, transport costs will be reduced by 13–15% from Storstrøm to Hamburg and by about 17% from Kreis Ostholstein to Copenhagen. By rail, cost savings are greater, but they depend in part on assumptions concerning how many stops an inter-city or a high-speed train will make. Today, the journey from Copenhagen to Hamburg takes 317 minutes by rail. With HST stopping in Lübeck the journey would take only 120 minutes and with three stops 150 minutes, whilst the IC rail link will take 190 minutes. From Storstrøm to Hamburg, travel times could be reduced to 45% of current travel time using HST and from Kreis Ostholstein to Copenhagen travel times could be reduced to 38%. What is also significant is that the HST option stopping in Nykøbing Falster in Denmark reduces the travel time from Nykøbing Falster to Copenhagen from 99 minutes today to 45 minutes, whilst the IC option reduces travel time to 75 minutes. Thus, the Femern link also has implications for travel times and costs within each country.

STORSTRØM COUNTY AND KREIS OSTHOLSTEIN: THE REGIONAL CONTEXT

Storstrøm County, with an area of 3,400 km^2, is three times larger than Kreis Ostholstein, though each county constitutes about 8% of the area of Denmark and Schleswig-Holstein respectively. GDP per capita at factor cost in Storstrøm County in 1992 was DKr 97,951 or 68·6% of the national average. For Kreis Ostholstein the corresponding figure in 1988 was DM 21,360 or 63·8% of the West German average. The industrial structure in the two regions is different. In Storstrøm County the primary sector accounted for 13·1% of regional GDP in 1992 whilst in Kreis Ostholstein it accounted for only 6·4% though in both cases the primary sector (mainly agriculture) is over-represented compared with its national share. In each county, manufacturing accounts for around 20% of GDP, which in the case of Ostholstein is substantially smaller than the national share, whilst in the case of Storstrøm it corresponds approximately to the Danish national average. Trade and transport account for 25·0% of regional GDP in Storstrøm County and 17·1% in Ostholstein, in both cases close to the national average. However, in both counties the share of the transport sector is substantially above the national average (mainly because of the maritime border) whilst the share of commerce is below. Finally, other services constitute 42·8% of GDP in Storstrøm County as compared to 47·5% at national level, whilst in Kreis Ostholstein they comprise 54·7% compared with 42·5% at national level. These differences represent in part the relative importance of tourism in the Ostholstein regional economy. The labour force resident in Storstrøm County was 136,800 in 1992 and in Kreis Ostholstein 84,000 in 1987. The southern half of Storstrøm County, furthest from Copenhagen, faces more severe economic problems than the northern half, closer to Copenhagen. In 1992 there were 16,925 unemployed in Storstrøm County (full time equivalents) or 12·8% of the regional labour force, whilst in Denmark 11·4% of the labour force was unemployed. However, in some municipalities in the south of the county unemployment percentages exceeded 16. In Kreis Ostholstein in May 1993 there were 5,085 registered unemployed or 6·5% of the labour force. Seasonal effects mean that this figure is somewhat higher in the winter months. The unemployment problem remains, however, more serious on the Danish side.

ANALYSIS OF THE REGIONAL ECONOMIC EFFECTS OF CHANGES IN TRANSPORT INFRASTRUCTURE AND TRANSPORT TECHNOLOGY

It is usual to regard the regional economic effects of changes in transport infrastructure as being of three main types:

1. The initial effects associated with the period of construction, where the multiplicative effects of large-scale infrastructure investment on regional economies are of interest
2. The short and medium term effects of the opening of the link on production, employment and incomes by region, including changes in patterns of inter-regional trade; changes in regional competitiveness are the key to explaining such changes
3. The long term dynamic effects of the opening of the link on such questions as location of production, commuting patterns, labour market structure, industrial organization, logistics, etc.

The short and medium term effects are the main concern of the present modelling exercise. The initial effects can be analysed using standard regional input–output techniques, whilst the long term dynamic effects are very difficult to model, though within the present study some attempt has been made to examine these effects.

There are a number of alternative methodologies for *ex ante* evaluation of the regional economic impacts of changes in transport infrastructure and technology (see, for example, BJØRNER *et al.*, 1993; RIETVELD and NIJKAMP, 1993; JENSEN-BUTLER and MADSEN, 1996a). These are reviewed below in relation to the present study and an ideal modelling approach is presented.

Stated preference

This qualitative approach involves the use of interview and questionnaire techniques at the level of the firm designed to examine decision makers' views and to forecast the future behaviour of firms after infrastructure investment has taken place. An *ex ante* stated preference approach has been used by ILLERIS and JAKOBSEN, 1991, with Danish firms in an attempt to evaluate potential effects of the opening of the Great Belt link. SIMON, 1987, provides an example of an *ex post* analysis (using revealed preference) of the effects of the opening of the Humber Bridge in the UK. BONNAFOUS, 1987, presents interview-based results concerning the effect of the high-speed rail link (TGV) on regional economies and location along the Paris–Lyon axis. As RIETVELD, 1996, points out, this approach to evaluation is problematic for a number of reasons, including lack of precision, bounded rationality of respondents and incomplete knowledge. It also tends to ignore the indirect and induced effects on other firms on the regional economy as a whole. A general empirical result of this type of approach seems to be that the effects of transport infrastructure investment are limited. The approach was not adopted here for these reasons, reinforced by the fact that the existence of an international border makes problems of information and bounded rationality even more serious. The work of a consortium (ACT Consultants, Institut für Raumplanung, Universität Dortmund, Marcial Echeniques Postners) for the European Commission on the regional impact of the Channel Tunnel (ACT/IRPUD/ME&P, 1992) also deserves mention, as here a modelling approach has been developed which also incorporates interviews and stated preference.

The production function approach

Using regional macroeconomic data, this is an aggregate macroeconomic modelling approach, involving estimation of a regional production function for individual sectors, where transport infrastructure enters as an independent supply-side element (see, for example, RIETVELD, 1989; JOHANSSON, 1993). A function of the following type is usually specified:

$$Y_{ir} = f_{ir}(L_{ir}, K_{ir}, TI_{ir}, OI_{ir}) \quad (1)$$

where:

Y_{ir} = value added in sector i in region r
L_{ir} = employment in sector i in region r
K_{ir} = stock of private capital in sector i and region r
TI_{ir} = transport infrastructure in region r
OI_{ir} = other infrastructure in region r.

BRUINSMA *et al.*, 1991, provide a list of studies undertaken in Europe and Japan from 1970 onwards using this type of approach. Most use a Cobb–Douglas production function, implying a high level of substitutability between inputs. JOHANSSON and MATTSON, 1993, document the wide range of output elasticities obtained from different studies using this approach. In ASCHAUER's, 1989, study, dealing with infrastructure in general rather than specifically transport-related infrastructure, he found a high coefficient of 0·39 for US data, whilst lower coefficients have been identified for specifically transport infrastructure investments. The American Federal Highway Administration places more credibility on these lower coefficients, which tend to bunch in the range 0·15–0·25.

The production function approach has been largely used for *ex post* analyses of the regional economic effects of infrastructure investment, but could, in principle, be used *ex ante*. In this study the approach could not be adopted because of lack of regional capital stock data on the German side. In addition, data on the value of infrastructure is unreliable.

The accessibility approach

This approach is usually based upon an aggregate measure of accessibility for each zone in a zonal system in a pre-investment situation. This is then compared to a recalculated accessibility measure after a transport infrastructure investment has been made. Economic potential, derived from a potential model such as that shown in equation (2), has often been used as an aggregate accessibility measure:

$$P_i = \sum_{j=1}^{n} (E_j \cdot c_{ij}^{-\beta}) \qquad (2)$$

where:

P_i = economic potential in zone i
E_j = employment in zone j
c_{ij} = transport cost from zone i to zone j
β = parameter.

Economic potential is calculated for each zone in a set of zones before transport infrastructure investment has taken place. The appropriate interzonal c_{ij} values are then altered as a consequence of the provision of new transport infrastructure and the new accessibility measures are calculated for each zone. P_i can be interpreted as the level of accessibility of zone i to the entire zonal system, taking into account two variables: first, the level of economic activity in each zone (higher levels of economic activity contributing positively to potential values in other zones); and second, the generalized transport costs between zone i and each zone, including itself (higher costs lowering potential values). A major problem is the establishment of a representative value for the intrazonal generalized transport costs in zone i (BRÖCKER, 1989). Relating changes in potential value to changes in regional income and employment is difficult, though a solution was developed in the context of the present study as described in a following section. Examples of the use of this type of approach are provided by JENSEN-BUTLER and MADSEN, 1997, in the case of the three fixed links of the Western Baltic and by EVERS *et al.*, 1987, who use this type of model to evaluate the regional economic effects of the proposed high-speed rail link from Brussels to Amsterdam and Hamburg. Their model includes more terms than the simple potential model described above, incorporating a border effect, a modal split effect and an *employment at risk* factor. One of the weaknesses of these types of accessibility approach is that they tend to regard change in accessibility in a simple zone-to-zone relation, rather than including network improvements as a whole. Accessibility in any zone can be affected in a dynamic framework by changes in accessibility between two other zones. Thus, the effects in improvement of the network as a whole are probably underestimated. In other words, the methodology probably underestimates the positive externalities associated with improvements in transport infrastructure. As will be seen below, the accessibility approach was incorporated in the overall approach to evaluation of the Femern link. Data requirements and availability played a major role in the decision to use this type of approach.

Transport modelling approach

One common approach to the evaluation of the consequences of transport infrastructure investment has been to concentrate attention upon regional changes in activity in the transport sector itself. This type of study includes both descriptive analyses of changes in transport systems and related changes in generalized transport costs in different regions which arise from transport infrastructure investments, in addition to traditional traffic modelling exercises, often using a sequential traffic model (WILSON, 1974). This latter type of study typically produces estimates of new traffic flows, changes in modal split and changes in route choice. Usually, assessment of the regional economic consequences of such changes are limited to consideration of the direct effects arising from changes in transport costs or, alternatively, simple employment multipliers are calculated. Examples of this type of approach include ILLERIS and JAKOBSEN, 1991, who have compiled isochrone maps of Denmark before and after the opening of the Great Belt Link and PLASSARD, 1977, who has used this type of approach in a number of studies including the estimation of the effects of the Paris–Lyon TGV link. A problem with this approach is that it is usually only the direct effects of changes in the transport system which are included in the analysis. The wider regional economic effects and consequences for consumer and producer behaviour are often ignored and, within the constraints of the approach, are also difficult to model.

An integrated approach

Theoretically, a more satisfactory type of approach to this problem should involve the simultaneous and mutually interactive effects of changes in regional economic activity and changes in transport and trade flows induced by transport infrastructure and changes in transport technology (JENSEN-BUTLER and MADSEN, 1996a, 1996b). There are few examples in the literature of applications of the integrated approach. The study referred to earlier on the regional impact of the Channel Tunnel (ACT/IRPUD/ME&P, 1992) builds on an integrated framework, though the model equations are not fully specified.

This approach involves the integration of an interregional macroeconomic model with a transport model. Ideally, the macroeconomic model should be of the interregional general equilibrium type as this would include explicitly producers' and consumers' decisions as a consequence of changes in transport costs. As the transport model component, the four-stage sequential transport model involving a double-constrained entropy-maximizing model (WILSON, 1972) would be appropriate. The two sub-models are integrated and used to model different types of interregional flow: trade (including passenger travel in the service sector), commuting, shopping and leisure and tourist trips. In the macroeconomic model, flows are treated in national accounting (monetary) terms, whilst in the transport model, physical units (for example ton kilometres) are used. The present authors have developed a model, AIDA, along these lines (JENSEN-BUTLER and MADSEN, 1996a, 1996b).

AIDA is a Keynesian income multiplier model with an interregional input–output model at its core. The structure of AIDA can be seen in Fig. 2. The model provides estimates of a large number of key regional economic variables, including:

- gross output by sector
- GDP at factor cost by sector (both by place of work and residence)
- employment by sector (both by place of work and residence)
- unemployment
- disposable income
- taxes and regional tax base
- transfer incomes
- private consumption by sector
- interregional export and import by sector.

The model operates with six production sectors, aggregated from a much larger number of sectors and with 12 Danish regions. In another version of the model, 10 sectors are used and 16 regions. The six sectors are:

- agriculture
- building and construction
- transport and telecommunications
- industry
- private service
- public sector.

Fig. 2 shows that there are two fundamental dimensions in the model. The first, vertical, dimension divides regional economic activity into three types of locality: place of residence; place of demand; and place of work/production. The second, horizontal, dimension relates to prices, incorporating both fixed and current prices using a GDP deflator. The introduction of a price model permits the incorporation of income effects of changing prices and, also, changes in relative prices enter into consumption functions for components of private consumption.

In AIDA there are seven categories of final demand:

- private consumption
- public sector consumption
- investment in machines and means of transport
- investment in buildings
- stocks
- export (international)
- imputed financial services.

Private consumption is subdivided into 11 different components which are treated endogenously in the framework of a Keynesian multiplier model. The remaining six categories of final demand are thus the exogenous elements which drive the model. The resulting GDP at factor cost by sector and by region is translated into disposable income, including taxation and transfer incomes (in current prices and finally transformed into 1980 prices) in each region. This, in turn, generates increases in private consumption via non-linear (national) consumption functions, which are fed back into the model to generate a new (but smaller) round of income increase.[1] Thus, the model is solved using a round-by-round method rather than by using the Leontief inverse, in order to incorporate consumption functions in the solution of the model. Interregional exports and imports (both imports for intermediate demand and for final consumption) are calculated endogenously in AIDA, where a double constrained entropy maximizing model is used to determine interregional trade flows and coefficients, given total exports and imports by sector and region. At each round, trade flows are recalculated, a process which continues until convergence occurs.

Ex post evaluation has been undertaken independently of this study to examine the performance of the model (MADSEN, 1991a). The input–output coefficients were kept constant at the level of the first year and the true values of the components of final demand were entered into the model, private consumption being generated endogenously as described above. The model was run for a 10-year period and the results for selected variables (for example employment and GDP by sector) were compared with data available from Statistics Denmark. The model performed satisfactorily: for example, it could predict sectoral/regional employment and gross output in most cases to within ± 3% of the actual value, the highest single deviation being 7%.

Seen in relation to the ideal integrated general equilibrium model, a number of limitations can be noted. First, AIDA is a demand-driven model rather than a general equilibrium model, which implies that changes in transport costs appear in the model partly as changes in interregional trade flows (a distributional effect) and partly as changes in the levels of interregional and international exports, through the exogenous use of a simple partial equilibrium demand elasticity approach (a generation effect). These issues are dealt with in more detail in JENSEN-BUTLER and MADSEN, 1996a. Second, the long term structural effects on investment and location of changes in the transport system are not included in the model. Third, the transport model component involves only monetary flows rather than physical transport volumes and, whilst the transport generation and distribution stages of the sequential transport model as well as route choice are included, the modal split sub-model is not.

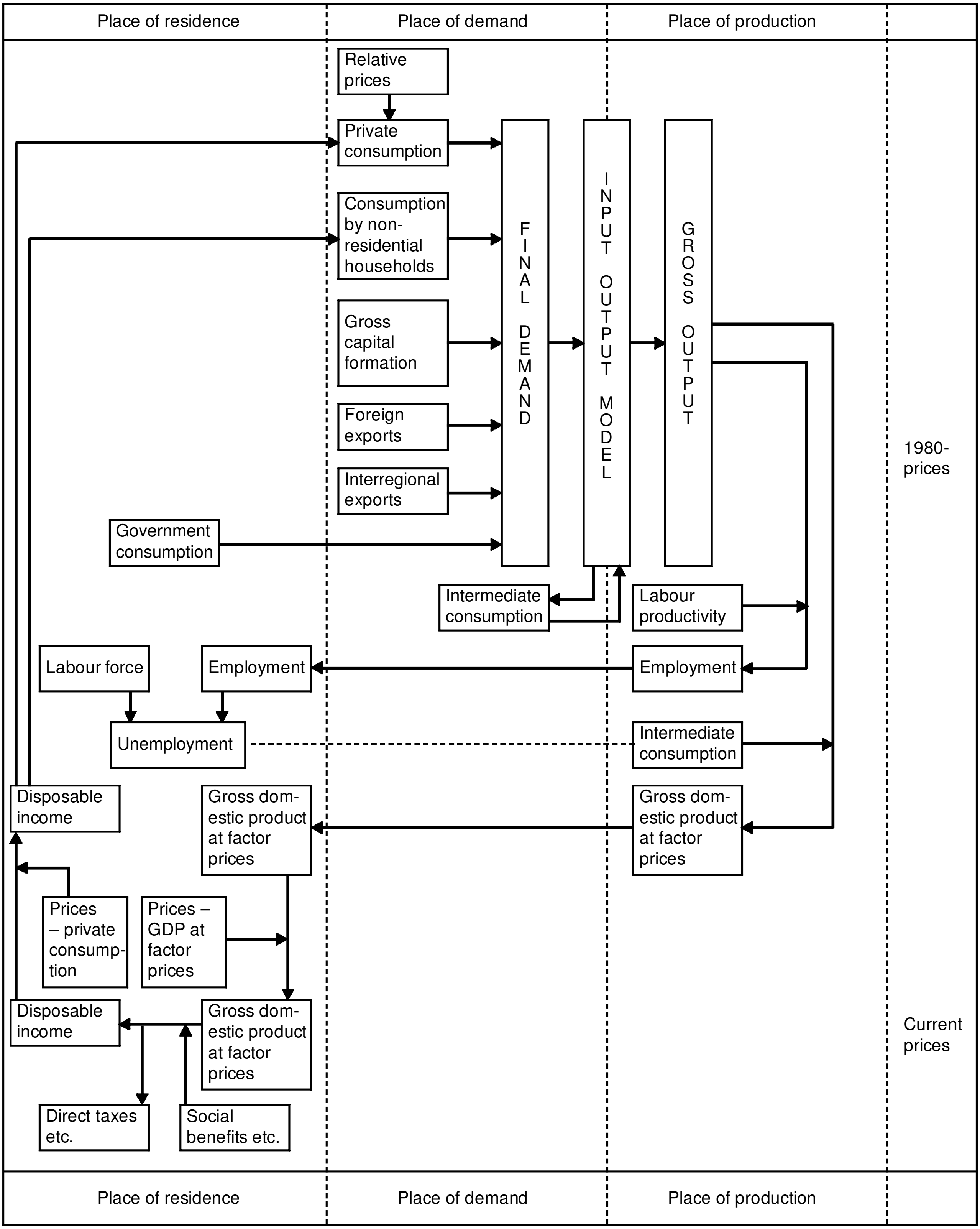

Fig. 2. The structure of AIDA

AIDA could be expanded to include long term effects on production and the labour market. The long term effects on production could be modelled by establishing a relationship between investments and an expression of user costs for firms trying to establish economic activity in a region. Changes in accessibility would then change user costs and investment in a region and increased investment would lead to greater production capacity in the long run. For households, improved accessibility would lead to changes in demand with respect to place of residence and also new commuting patterns. This, in turn, would lead to new spatial patterns of demand for services orientated to household demand. There is also a supply side effect as firms both inside a region and elsewhere gain access to a larger and more diversified labour market which improves productivity and lowers costs.

The evaluation of the regional economic effects of the Femern link could not use the integrated approach embodied in AIDA, as interregional trade data and regional accounts do not exist for the wider western Baltic region, including German *Länder* and Swedish *Län*. These data only exist for Denmark, which renders impossible the development of this type of model for the regions involved. In addition, such an analysis would have required the inclusion of long term components such as an investment and location model, as well as a major extension of AIDA to include a full traffic model, with modal split and improved route choice models which, whilst not impossible to undertake, would have placed major demands both on data and modelling.

For these reasons, a less integrated and a theoretically more eclectic approach to the problem of evaluation was adopted. This approach is examined in the next section, where theoretical comparisons with the ideal approach described above are also made.

MODELLING THE EFFECTS OF THE FEMERN LINK USING AN ECLECTIC APPROACH

Three main types of short and medium term regional economic effect of investment in transport infrastructure can be identified:

1. The regional economic effects of changes in transport technology, where different technology alternatives are considered: here, this is the opening of a fixed link and the closure of ferry routes
2. Changes in regional economic activity arising from changes in patterns of regional competitiveness as a consequence of changes in costs and prices: changes in competitiveness have both medium term effects on the production of existing firms and long term effects on the location of new firms and closure of existing firms
3. The regional economic effects of changes in traffic flows along different corridors, including effects appearing through changes in levels of demand in transport-related activities such as hotels and restaurants.

In principle, all three effects could be modelled using an integrated approach. In the following, second-best solutions have been applied for reasons explained above and results from each of the three components of the medium term analysis are presented, followed by a summary of the total estimated changes. Effects are examined in relation to two different scenarios: (1) comparison of the situation today with two fixed links; and (2) comparison of the situation today with three fixed links, which permits isolation of the pure effect of the Femern link.

Changes in transport technology

Major transport infrastructure investments usually involve a change in modal split, which in turn involves changes in level of economic activity in the transport sector, reflected in changes in employment. In the case of the Femern link, it is assumed that the opening of the link involves closure of the ferry routes in the same corridor. This means that the question of retaliatory pricing by ferry companies does not arise. In principle, the probability of complete or partial ferry closure could have been modelled using an AIDA-type of model. Here, these changes have not been modelled, but assuming that fixed link tolls are at the same level as ferry prices, the major time savings involved warrant this assumption. Furthermore, in the current debate concerning the link, it does not seem to be an option that ferry routes (except possibly tourist excursion ferries without cars) will continue after the fixed link is established. The company at present operating the ferries is owned by the Danish State Railways and they will have a major interest in the success of the fixed link. It is therefore reasonable to assume that economic activity related to the ferries is substituted completely by activities related to alternative modes, for example, rail shuttle related activity or bridge infrastructure maintenance and toll collection.

The point of departure for assessment of changes in economic activity arising from changes in transport technology is a concrete assessment of the changes in employment related to each of the transport technology alternatives under consideration, these being the direct effects. The estimates of the direct effects on employment were derived from interviews with the ferry company and are based upon changes in the transport sector itself, the hotel and restaurant sector (on the ferries) and estimates of personnel required to operate the new transport solution. Personnel employed in the duty-free shops on board the ferries are not included, as they will disappear in any case because of changes in EU regulations.

The indirect and induced effects of these changes have been modelled using a one-region macroeconomic model, EMIL, developed at the Local Governments' Research Institute (AKF) in Copenhagen (MADSEN, 1991b). There is a version of EMIL for each of 16 Danish counties and in this case the model for Storstrøm County was used. EMIL is a one-region version of AIDA where interregional elements, such as trade and commuting are exogenous rather than

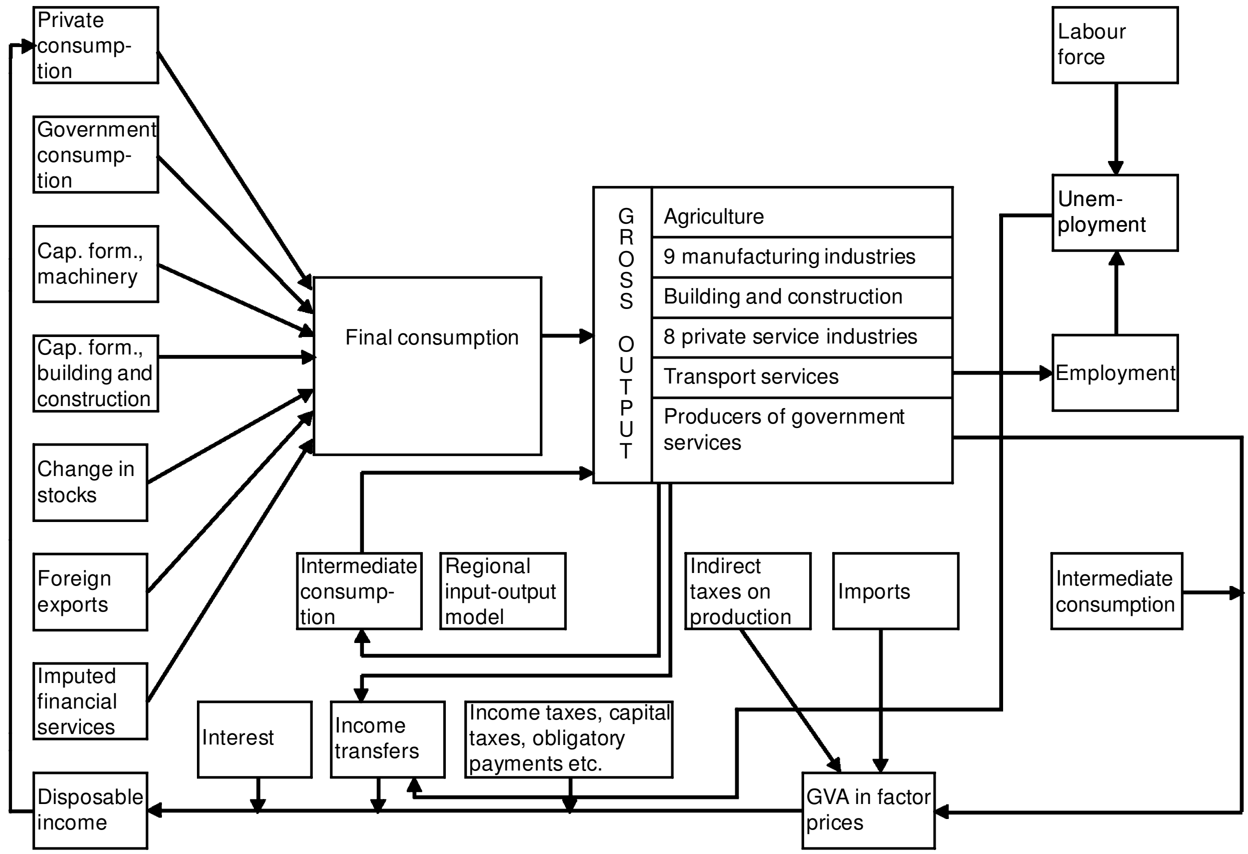

Fig. 3. The structure of EMIL

endogenous; its structure can be seen in Fig. 3. EMIL is a Keynesian demand-driven model, where private consumption is endogenous, permitting the use of consumption functions within the model, as in AIDA. At the core of EMIL is a regional input–output model, which is used to assess changes in key macroeconomic variables at the sectoral level. In EMIL, 21 production sectors are represented together with 17 components of final demand. The model is solved using a round-by-round iterative method, rather than by use of the Leontief inverse, permitting the use of consumption functions during the solution procedure.

In the model the exogenous components (private consumption being endogenous) of final demand are given, whilst the values of the endogenous variables (gross output, GDP, employment, etc.) are calculated iteratively, using an adapted Gauss–Seidel solution routine, until a stable solution is found. In the present analysis, the input to the model is a change in employment in the transport sector (the direct effect) which is normally an endogenous variable in the model. Therefore, an ends–means analysis was undertaken; technically, exports, chosen simply as a suitably neutral component of final demand, are reduced until employment in the transport sector corresponds to the level given by the exogenous direct change. The model then produces estimates of the total (direct, indirect and induced) effects on gross output, GDP and employment, by sector.

The direct consequences for employment in both Storstrøm County and Kreis Ostholstein have been estimated for two transport technology strategies: (1) a rail-only link with a shuttle; and (2) a multi modal bridge link. Calculations have only been made for Storstrøm County, as a model cannot be constructed for the German side. The direct effects are identical on the German side and, as the two regions have a similar economic structure, it is reasonable to assume symmetry on each side of the Femern Belt, so that similar results can be assumed to hold in Kreis Ostholstein.

Compared with the situation of no fixed links, three fixed links will reduce direct employment in total by 1,050 in each of Storstrøm County and Kreis Ostholstein for a rail shuttle solution and by 1,150 for a multimodal solution. This can be compared with the situation with two fixed links and no Femern link, where the direct loss of employment will be 200 in each of the two regions because of reduced traffic flows using this corridor. A traffic model was developed as a part of the study, this being described below. This model was used to estimate the decline in traffic using the Femern Belt ferries as a consequence of the opening of the two fixed links. This decline was translated into direct effects and then, using the modelling approach,

Table 1. Direct, indirect and induced effects on employment and regional GDP in Storstrøm County for three fixed links and for the effects of the Femern link alone, using different transport technologies

	Employment effects: three fixed links				Employment effects: created by Femern link			
	Employment (jobs)		GDP (% change)		Employment (jobs)		GDP (% change)	
	A	B	A	B	A	B	A	B
Primary	− 20	− 20	− 0·3	− 0·3	− 20	− 20	− 0·2	− 0·2
Secondary	− 90	− 90	− 0·4	− 0·4	− 70	− 80	− 0·3	− 0·4
Transport	− 710	− 810	− 4·5	− 5·1	− 560	− 660	− 3·5	− 4·4
Hotel and restaurant	− 350	− 350	− 6·1	− 6·1	− 300	− 300	− 5·3	− 5·3
Other service	− 160	− 180	− 0·2	− 0·2	− 130	− 140	− 0·2	− 0·2
Total	− 1,330	− 1,460	− 1·1	− 1·2	− 1,080	− 1,200	− 0·8	− 1·0

Note: A: rail shuttle; B: multimodal.

the total effects were derived. These results suggest that the direct effect for each of the two counties of establishing a fixed Femern link, after opening of the other two fixed links, will be a loss of 850 jobs for a rail shuttle solution and 950 for the multimodal solution.

Table 1 shows the total effects on employment and regional GDP at factor cost for Storstrøm County of the estimated direct reduction in employment. The table shows estimates for the two transport technology options, for the three fixed links and for the Femern link alone, permitting an assessment of the synergy effect of all three links. A total loss of 1,460 jobs with the multimodal solution and 1,330 with the rail shuttle solution is forecast, corresponding to about 1·7% of the regional labour force. The growth in unemployment is estimated to be somewhat less, as some people will leave the labour force. If the two other fixed links are already established, then closure of the Femern ferry route and establishment of a fixed link (the pure Femern effect) will result in a loss of jobs of 1,200 for the multimodal solution and 1,080 for the rail shuttle. Except for the transport and hotel and restaurant sectors, where the decline in regional and sectoral GDP lies between 3·5% and 6·1%, the decline in GDP is modest; for the region as a whole it is estimated to be around 1%. With respect to the results for Kreis Ostholstein, it is assumed that the direct employment loss from the ferry closures is the same as on the Danish side and that, as the structure of the two economies is very similar, the indirect and induced effects of these changes will be of the same magnitude.

Changes in regional competitiveness

Again, ideally a model of the AIDA type for the entire western Baltic area should be used to estimate changes in regional competitiveness. As argued above, the model could be used to estimate the effects on the distribution of regional trade flows arising from changes in generalized transport costs after the opening of three fixed links. It could also be used to estimate the overall change in regional economic activity by region both in the medium term and also in the long term if locational consequences are included in the model (see above). However, data constraints do not permit use of this type of approach. Therefore, in order to assess changes in regional competitiveness, the more simple accessibility approach was adopted, based upon a potential model along the lines described above.

As transport costs change after the construction of a major infrastructure project, regional accessibility also changes, implying changes in patterns of regional competitiveness. An economic potential model involving 100 zones in Europe, derived from the 180 zones referred to earlier, was set up. In Denmark, Sweden, Norway and Finland the zones are the counties; in Germany the zones are the *Länder*, except in Schleswig-Holstein, where the counties (*Kreis*) are used; the Netherlands, Belgium, Switzerland and Austria are treated each as single zones. A centre of gravity for each zone was determined and an economic potential model of the type shown in equation (2) was constructed for the entire system. The value of β was set to 1, the same as that used in an earlier study of accessibility in the European Union (COMMISSION OF THE EUROPEAN COMMUNITIES, 1990) and the same value of β was used for all forms of transport. Potential values were calculated for each zone, in four successive calculations: (1) before the opening of any fixed link, followed by the successive opening of: (2) the Great Belt link; (3) the Øresund link; and finally (4) the Femern link.

After having derived the changes in potential values the next problem is to translate these changes into changes of level of economic activity. This problem was solved in an arbitrary manner by EVERS *et al.*, 1987, who assumed that changes in employment would be proportional to changes in potential. In the present study, independent estimates of changes in regional economic activity in Denmark as a consequence of the opening of the Great Belt link exist (MADSEN and JENSEN-BUTLER, 1992). In this 1992 study AIDA was used to obtain estimates of changes in key macro-economic variables at regional and sectoral levels as a consequence of the opening of the Great Belt link.

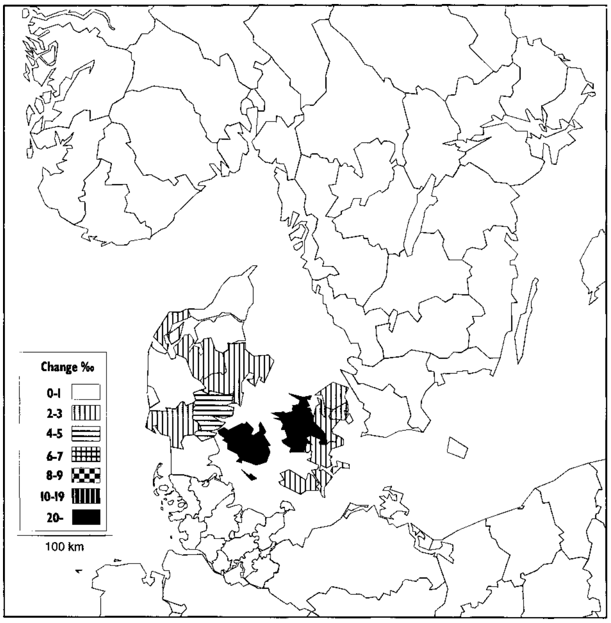

Fig. 4. Changes in economic potential (per thousand) after the opening of the Great Belt link

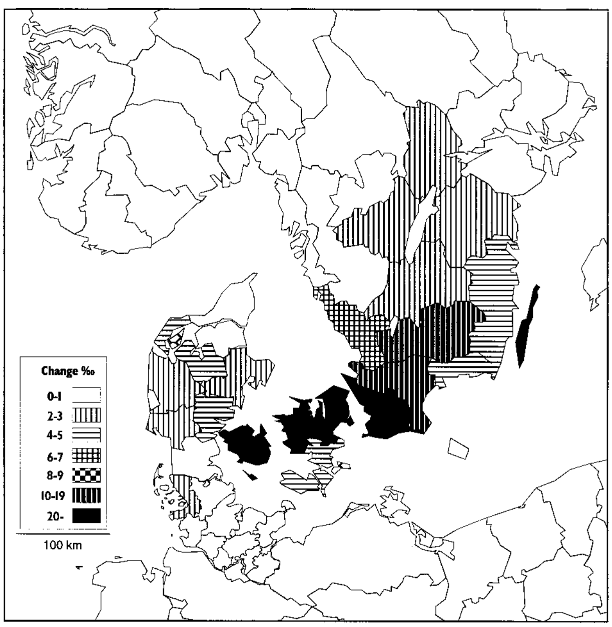

Fig. 5. Changes in economic potential (per thousand) after the opening of the Great Belt and Øresund links

Estimates of changes in regional employment (direct, indirect and induced) for Danish counties provide a benchmark by which the changes in economic potential can be calibrated, as estimates exist both for changes in economic potential and for changes in economic activity, by Danish region. These enable estimates of total employment changes arising from changes in regional competitiveness, measured by changes in economic potential, to be made for a wider area.

Figs. 4–6 show changes in regional economic potential as each of the three fixed links is added successively to the transport system. The effects of the Great Belt link (Fig. 4) are exclusively Danish. Potential values increase most in the two regions adjacent to the link and in some counties in Jutland. The addition of the Øresund link (Fig. 5) creates a strong belt of increased potential values from south Sweden across Denmark. Finally the addition of the Femern link (Fig. 6) has strong effects on potential values where increases stretch well up into Sweden and also affect Storstrøm County. There are also marginal effects in Schleswig-Holstein. The increases in southern Scandinavia and the absence of large increases in northern Germany arise from the fact that southern Scandinavia gets improved access to the large German market, whilst access to a more limited Scandinavian market does not affect German regions as much.

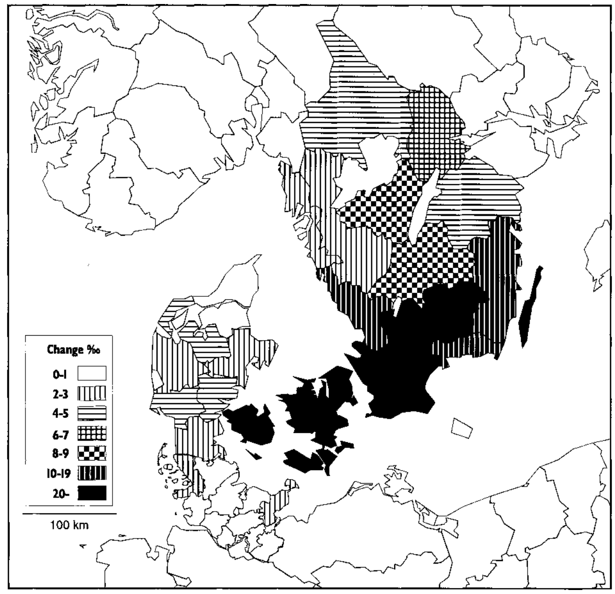

Fig. 6. Changes in economic potential (per thousand) after the opening of all three fixed links

Table 2. Successive total employment effects (number of jobs) of increased competitivity as a consequence of the three fixed links

	Storstøm County	Denmark	Kreis Ostholstein	Schleswig Holstein
1. Great Belt link	50	2,000	0	0
2. Øresund link	100	4,000	0	100
3. Femern belt link	300	5,500	100	500

Note: Results are cumulative down the columns.

Using the methods described above, the cumulative effects on employment of increased competitiveness as a consequence of sequential establishment of the three fixed links are shown in Table 2. The figures are rounded because of the uncertainty involved. For Denmark, the combined effect of the Great Belt and

Øresund links is somewhat greater than the effect of the Femern fixed link. For Storstrøm County, in relative terms, the employment effect of the Femern link is greater. The employment effects in Germany are modest and are concentrated in Schleswig-Holstein.

Inside Denmark, it seems that the positive effects of improved competitive position largely benefit Greater Copenhagen, which takes the major share of the estimated Danish employment increase.

Long term effects on the labour market

The Femern project consists in reality of two parts. The first is the construction of a fixed link across the Femern Belt. The second part is the related, but partly independent improvements to the existing rail networks in both countries. On the Danish side this could mean either an HST rail link between Copenhagen and Storstrøm County (continuing to Hamburg) or only upgraded IC services. The HST solution, unlike the IC solution, will of course have no consequences for commuting, if there is no stop in Denmark in Nykøbing Falster. From the point of view of Storstrøm County, an upgraded, faster IC (and for passengers cheaper) rail service may have more significant effects in the long term as the region will become markedly more attractive as a residential area for commuters to Copenhagen, offering cheap housing and a green environment. In the very long term, improved rail transport and a growing and qualified labour force could prove to be attractive for firms which find advantage in a central location between the cities of Copenhagen, Hamburg and Berlin, whilst at the same time being able to choose an attractive environment.

An attempt has been made to examine the long term structural effects of these transport infrastructure investments. The approach is empirical as it takes the form of calculations based upon an example rather than as the results of a modelling exercise. It has been assumed that the introduction of IC or HST rail services, with a stop in Nykøbing Falster, will change markedly the accessibility of southern parts of Storstrøm County to the Copenhagen labour market. This will permit more people in Storstrøm County to work in Copenhagen and the region will become a more attractive residential area for long-distance commuters. It is therefore reasonable to assume that the present-day number of commuters from Storstrøm County to Copenhagen will increase. In order to assess the magnitudes involved, the direct, indirect and induced economic consequences of a relocation of 1,000 in-migrants to Storstrøm County, where the source of household income lies outside the county, have been calculated experimentally using EMIL. The figure of 1,000 in-migrants has been chosen arbitrarily by way of illustration. No allowance has been made for the effects of increased inward migration on land and property prices, which will offset the increased attraction of the area.

It is assumed that 500 out of the 1,000 migrants are adults of working age, whose income is earned in the Greater Copenhagen area. Further, it is assumed that the increased tax income for local governments is partly used for creating public services for this increased population. The results indicate that 500 commuters are estimated to create an increase in local employment of 270 jobs, where the public sector has the most important share. The model estimates that unemployment will only decline by 160 because of increased participation in the labour force. This corresponds to an increase in regional GDP at factor cost of 0·2%, arising alone from inward migration of employed people and their families; the factor incomes of the employed inward migrants are accounted for in the region where they work. The increase in GDP and employment arises from the induced effects arising from increased demand for locally produced goods and services.

It is very difficult to forecast the number of in-migrants in the long term, but the above results seem to suggest that the positive impact of such immigration is substantial. However, such positive long term effects are more related to improvements in the rail network inside Denmark than to the establishment of a fixed link. Therefore, from the point of view of Storstrøm County and Denmark, it seems relevant to undertake separate socio-economic assessments of the fixed Femern link and the HST service on the one hand and an improved IC service on the other. Inside Storstrøm County it is the areas close to the railway which will benefit more from increased commuting, whilst it is the more peripheral parts of the county which will suffer from closure of ferry services.

The modelling framework developed here does not permit analysis of the potentially positive effects on labour markets elsewhere of improved accessibility from Storstrøm County, which could lead to some increase in demand for labour in Storstrøm County. An interregional general equilibrium model with a labour market component would be necessary for this purpose.

Changes in traffic flows

The Femern link will have major effects on the choice of traffic corridor between Scandinavia and the rest of Europe. Seven traffic corridors were identified, as can be seen in Table 3. After the opening of the two first fixed links it is to be expected that some traffic to Europe will divert from the Femern corridor and the Swedish ferry links, using the Øresund and Great Belt fixed links and the land border crossings between Denmark and Germany. Again, an ideal solution for modelling these changes would be the use of an integrated model. However, constraints on this type of

Table 3. Market shares for transport corridors between the Nordic countries and the rest of continental Europe (1992) and after the opening of two and three fixed links (%)

	Cars			Lorries		
	Today (O_1)	Two fixed links (O_2)	Three fixed links (O_3)	Today (O_1)	Two fixed links (O_2)	Three fixed links (O_3)
Land border Jutland/Schleswig-Holstein	38·3	40·4	38·3	65·6	68·0	64·1
Fynen (ferries)	4·8	5·4	7·3	0·0	0·0	0·0
Norway/West Sweden/Zealand–Continent (ferries)	4·7	3·9	2·1	3·1	2·5	1·5
Rødby–Puttgarten (Femern corridor)	33·0	30·8	41·9	12·2	11·2	19·7
Gedser–Rostock ferry	5·6	5·9	4·3	1·7	1·7	1·4
South and East Sweden–Continent (ferries)	12·6	12·1	3·6	17·1	16·1	12·8
Finland–Continent (ferries)	1·0	1·5	1·4	0·3	0·4	0·5
Total	100·0	100·0	100·0	100·0	100·0	100·0

modelling approach relate to regional accounts whilst data on international transport flows do exist. Therefore, three elements (a trip distribution model, a modal split model and a route choice model) taken from the standard four-step sequential transport model (WILSON, 1974) were used to examine changes in traffic flows, using transport data for Europe, including the western Baltic area.

For passenger traffic, and using data on transport flows between 180 zones in Europe, the first step was to model trip distribution, using a double constrained entropy maximizing model:

$$T_{ij} = A_i B_j O_i D_j e^{-\beta c_{ij}} \quad (3)$$

where:

T_{ij} = traffic flow from region i to region j
O_i = traffic flows originating in region i
D_j = traffic flows with destination in region j
$e^{-\beta c_{ij}}$ = generalized cost function for travel $i-j$.

A_i and B_j are defined as follows:

$$A_i = \left(\sum_j B_j D_j e^{-\beta c_{ij}}\right)^{-1}$$

$$B_j = \left(\sum_i A_i O_i e^{-\beta c_{ij}}\right)^{-1}$$

In terms of data, it was a major constraint for the present study that data on freight flows between a large number of zones in Europe and Scandinavia do not exist. Therefore, this part of the exercise has a weaker modelling foundation. In order to estimate changes in (rather than levels of) freight traffic along the different traffic corridors between Scandinavia and Europe, a production constrained gravity model was developed for the 180 zones, as shown in equation (4):

$$T_{ij} = eps_i \cdot \frac{eps_j \cdot c_{ij}^{-\beta}}{\sum_j eps_j \cdot c_{ij}^{-\beta}} \quad (4)$$

where:

eps = employment in primary and secondary sectors by zone
c_{ij} = generalized transport costs between zones i and j.

The value of the coefficient of 0·05 was taken from a Danish study of freight traffic (JENSEN-BUTLER and MADSEN, 1996a) and the values of *eps* were calculated from European statistics.

Then, given the distribution of flows, choice of transport mode for passenger traffic was estimated, using a modal split model. The model was calibrated using logistic regression on O–D data for the 180 European zones. For passenger transport three modes were used, air, road and rail, whilst for freight it was assumed that route choice will not change and no modal split model was developed. These assumptions concerning the freight sector are related to the fact that road transport is completely dominant and also because both rail and road modes face almost identical changes in generalized transport costs. In addition, lack of data prevents calibration of a modal split model for freight.

The passenger traffic model was a two-step model, where the first choice is between private (car) and public (train and air) modes. Given public transport, the second choice is between train and air. The probability of choosing public transport is given by equation (5):

$$P(ctm) = \frac{\exp(-0{\cdot}0691 - 0{\cdot}00964 \cdot dc_{ij}^{ctm})}{1 + \exp(-0{\cdot}0691 - 0{\cdot}00964 \cdot dc_{ij}^{ctm})} \quad (5)$$

where: $dc_{ij}^{ctm} = \min(c_{ij}^{rail}, c_{ij}^{air}) - c_{ij}^{car}$.

The probability of choosing car is thus:

$$P(itm) = 1 - P(ctm)$$

Given the choice of collective transport mode, the probability of choosing rail is:

$$P(rail|ctm) = \frac{\exp(-0{\cdot}8594 - 0{\cdot}00304{\cdot}dc_{ij}^{rail})}{1 + \exp(-0{\cdot}8594 - 0{\cdot}00304{\cdot}dc_{ij}^{rail})} \quad (6)$$

where:

$$dc_{ij}^{rail} = c_{ij}^{rail} - c_{ij}^{air}$$

Given the choice of collective transport, the probability of choosing rail is:

$$P(rail) = P(rail|ctm) \cdot P(ctm)$$

$$P(air) = (1 - P(rail|ctm)) \cdot P(ctm)$$

The final step was construction of a simple route choice model based upon the all or nothing principle, involving 100% choice of route with the lowest generalized costs.

The three-step model was rerun: (1) for the situation after the opening of the first two fixed links; and (2) after all three links are open. Table 3 shows the results of this modelling exercise. After the opening of the first two fixed links there will be, as expected, a small decline in traffic, both passenger and freight, using the Femern corridor. At the same time, the Gedser (Storstrøm County)–Rostock (Germany) ferry route experiences an increase in passenger traffic, though more modest than the decline in the Femern corridor. After the opening of the Femern link, the Femern corridor more than recovers its market share, rising to almost 42% for passenger traffic and 20% for freight, thus gaining an important market share, mainly from the south Sweden ferry routes, whilst the Gedser–Rostock route declines to a level a little below that of today.

In Table 3 the 1992 distribution by route (r), is based on observed (O_1) data. The modelling exercise then replicated this distribution with considerable accuracy (M_1). The changes with two (M_2) and three (M_3) fixed links were then calculated. The results (O_2 and O_3) in Table 3 are calculated as follows:

$$O'_2 = \frac{\frac{M_2^r}{M_1^r} \cdot O_1^r}{\sum_r \frac{M_2^r}{M_1^r} \cdot O_1^r} \quad (7)$$

These changes in traffic flows create changes in economic activity serving the demand arising from the transport sector. An increased traffic volume creates employment in the restaurant and hotel sector and other traffic-related sectors. Using *ad hoc* estimates of the direct effects, based on expert knowledge, an estimated 200 jobs in Storstrøm County, including indirect and induced effects, are created, these estimates being derived again from EMIL. Similar results are assumed to hold in Kreis Ostholstein. The decrease in activities on the Gedser–Rostock ferry route can be added and the result is estimated to be job loss of 300 in Storstrøm County.

SUMMARY AND CONCLUSIONS

Two main sets of conclusions can be derived from this study. First, *ex ante* estimates of the regional economic effects of the Femern link have been obtained. These results also permit evaluation of the synergy effects of the Femern link in relation to the other two fixed links. Second, an evaluation of the eclectic method used in the present study can be made.

Regional economic effects: a summary

The three types of regional economic effect modelled are summarized in Table 4 which, it should be noted, do not include effects which may arise from new patterns of commuting.

Table 4. Changes in employment due to the successive opening of three fixed links for Storstrøm County and Kreis Ostholstein with a multimodal alternative

	Effects of three fixed links, with HST/IC		Effects of two fixed links only: no HST/IC change		Pure Femern effect with HST/IC
	Storstrøm County	Kreis Ostholstein	Storstrøm County	Kreis Ostholstein	Storstrøm County
Closure Femern Belt ferries (complete or, in the case of two fixed links, partial)	− 1,500 (− 1,300)[1]	− 1,500 (− 1,300)	− 300	− 300	− 1,200 (− 1,100)
Improved competitiveness:					
firms	+300	+100	+100	0	+200
tourism	0	0	0	0	0
Changes in traffic flows:					
transport sector	− 300	0	0	0	− 300
other private service	+200	+200	0	0	+200
Total effect without more commuters	− 1,300 (− 1,150)	− 1,200 (− 1,050)	− 200	− 300	− 1,100 (− 1,000)

Note: 1. Figures in parentheses are for the rail shuttle alternative.

It can be seen from these results that the overall employment effect of the Femern link is negative both for Storstrøm County, which already faces a severe unemployment problem, and also for Kreis Ostholstein. The negative employment effect is primarily a result of the opening of the Femern link rather than the effects of the two other fixed links.

The positive medium term effects on regional competitiveness for the two counties are small compared to the negative effects arising from ferry closures. The positive medium term effect on competitiveness in Storstrøm County is primarily due to the Femern link and less to the two other fixed links. The positive effects on regional competitiveness will be greater in other regions more distant from the link, notably Greater Copenhagen and southern Sweden. Thus, whilst the regional economic effects for Storstrøm County and Kreis Ostholstein are on balance negative, Greater Copenhagen and southern Sweden will benefit. There will be few regional economic benefits further afield on the German side.

The conclusion that regional economic effects will be modest is in broad agreement with some other studies of the regional economic effects of major transport infrastructure investment, notably the Channel Tunnel (VICKERMAN, 1987, 1997; VICKERMAN and FLOWERDEW, 1990, COST317, 1995; ACT *et al.*, 1992). A British consultancy firm forecasts gains of 14,450 jobs in the service sector and 33,300 jobs in manufacturing in the UK because of accessibility changes arising from the Channel Tunnel. They use a simple potential model, where the translation of changes in potential to changes in employment is not clearly documented, rendering the results somewhat dubious (SIMMONDS and JENKINSON, 1997). Vickerman makes the point that related and supportive investments (not being undertaken on the British side) could enhance considerably the regional economic effects of the Channel Tunnel. Here the immediate example is the major investment undertaken in France, in Lille, at the focal point of the TGV network between Paris, Brussels and London. The potentially comparative position of Storstrøm and Kreis Ostholstein in the centre of the triangle between Hamburg, Copenhagen and Berlin, also involving fixed link and high-speed rail links, appears. However, traffic flows are here much smaller, and there is as yet no commitment to construction of an HST link Copenhagen–Hamburg and an HST link from Ostholstein to Berlin is even less certain. The Humber Bridge (SIMON, 1987) provides another example of very modest regional economic effects of a fixed link, though in this case, there is no element of international traffic. The French Paris–Lyon TGV seems to create very limited regional economic effects (BONNAFOUS, 1987; PLASSARD, 1989). A recent Canadian evaluation of a proposed high speed rail link in the Quebec–Windsor corridor also indicates very limited regional economic effects, of the order of 13–14,000 new jobs in each of Montreal and Toronto (0·7–0·8% of total employment), though in percentage terms a little higher (1·2%) in Kingston, Ontario, a smaller city (MARTIN *et al.*, 1997).

Table 4 indicates that the difference in employment effects due to choice of transport technology on the Femern fixed link is small, though the loss of jobs is smaller for the rail shuttle solution. In general, the negative effects on employment and income are modest, both in absolute and relative terms, but are more substantial both for specific sectors and for peripheral areas in Storstrøm County and Kreis Ostholstein. The increase in traffic in the Femern corridor will partly compensate for these declines, but this compensation will be offset by loss of traffic on the more eastern ferry route (Gedser–Rostock) after the opening of the Femern link.

The overall picture is that the regional economic effects will be modest in the regions lying closest to the Femern link. In a longer perspective, the regional economic effects will probably be stronger in regions more remote from the link, namely Copenhagen and southern Sweden. In all events, the benefits seem to be almost exclusively Scandinavian rather than German, though some local positive economic effects in Schleswig-Holstein are probable.

What is difficult to model and forecast are the very long term regional economic effects of major transport infrastructure investments. These long term dynamic effects, including new commuting patterns and new patterns of location of economic activity, can potentially be substantial, as the simple modelling exercise undertaken here indicates. But they remain difficult to model. This is partly because, as both Vickerman and Plassard have argued, they depend very much upon the nature and extent of other forms of investment, as well as variables such as future fuel prices or GDP growth, which are very difficult to forecast.

The methodology

The approach used in the evaluation of the regional economic effects of the opening of a fixed Femern link from Denmark to Germany is theoretically eclectic and data from different sources have been both used and combined. Expert estimates have been combined with different modelling approaches and results from earlier evaluation exercises. An integrated approach based upon an interregional general equilibrium model would have been preferred, but this was not possible in this case, a situation that is common in this type of evaluation. The alternatives for evaluation are then either a more qualitative approach or an eclectic approach involving partial models. The present study indicates that an eclectic approach, using a more general model as a guiding principle for the partial analyses, can produce results whose information content is probably superior to the results obtainable from a qualitative approach, where the theoretical assumptions upon which the analysis rests are less clear. The underlying theoretical logic of each of the components of the present analysis has been made clear and, in theoretical terms, is defensible. There are of course, as in any eclectic approach, justifiable grounds for concern about the relative strengths of each sub-model as well as interfaces between the different sub-models.

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NOTE

1. The entire model, both the input–output component and the more general econometric model, are solved using an iterative procedure (Gauss–Seidel). In a Gauss–Seidel procedure the model equations are solved sequentially where the values of the endogenous variables are replaced instantaneously instead of at the end of each iteration. A factor which dampens the changes also enters the solution procedure. The advantage of this procedure, as opposed to the standard procedure of rendering private consumption and wages endogenous by inclusion in the basic transaction matrix, is that non-linear consumption functions can be used.

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Section 13:

Modelling Transport in an Interregional General Equilibrium Model with Externalities

Morten Marott Larsen, Bjarne Madsen & Chris Jensen-Butler

2 Modelling Transport in an Interregional General Equilibrium Model with Externalities

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Abstract. In this chapter the regional economic impacts of road pricing on cars are analysed taking into account externality effects from transportation on wages and productivity. The direct impacts from changes in transport costs on level of wages and productivity (the direct externality effects) have been estimated. The direct and derived economic impacts of road pricing have been evaluated using the sub-regional economic model LINE. The direct effects on level of wages and productivity have been included in the model together with all the direct effects on commodity prices from road pricing. The total impacts of road pricing have been subdivided into three components: 1) The wage effects of reducing income net of commuting by increasing transport costs with introduction of road pricing, 2) the labour contraction effect arising from increasing wages through increases in commuting costs and 3) the negative productivity effects of introducing road pricing. In total the impacts of road pricing are substantial. Regions with high level of average commuting costs (suburban areas in Greater Copenhagen) suffer most, whereas the centre of Copenhagen suffers least because of short commuting distances. In rural areas impacts are on or just below the average because of low levels of road pricing.

Keywords: Road pricing, Externalities, Transport costs, Regional economic model.

2.1 Introduction

It is customary to model transport in an interregional general equilibrium model without including the effects of both positive and negative externalities. In such a simplified model focus is usually directed at the price effects of direct changes in transport costs as the transport system is modified.

Negative externalities such as congestion and environmental damage can be incorporated either as a pre-model extension where transport costs include impacts from congestion, or as a post-model where environmental damage is modelled as a function of level of economic activity and as a set of emission coefficients. This is normally straightforward, as the pre- and post models are often linked in a loosely coupled system. In such a system, by definition feedback effects from the economic model to the pre-model (from the economic system to congestion, for example) and from the post-model to the economic model (from the environmental system to the economic system, for example) are not incorporated.

The inclusion of positive externalities is a more difficult task because it usually involves integration of the externality into consumption and production behaviour. This is because positive externalities normally have both impacts on economic activity and are influenced by the level of economic activity. This means that transport system improvements increase concentration (both number and density of firms) which in turn increases their productivity. On the other hand, increasing productivity reduces prices, increases competitiveness and thereby export and economic activity. These feedback mechanisms imply that modelling positive externalities should involve the application of an interregional general equilibrium model with productivity as a fully integrated sub-model.

In the following a theoretical approach to inclusion of positive externalities is examined. This is followed by an examination of the effects of transport system changes on economic activity, through an econometric study of Danish regions. In order to illustrate the distributional impacts on economic activity arising from positive externalities, an interregional general equilibrium model for Denmark is presented and results from a study using this model of the spillover and feedback effects of positive externalities are examined.

2.2 Positive Externalities

There is a considerable and growing interest in the effects of externalities on economic activity in space (Goodchild et al 2000, Anselin 2003a, 2003b, Fingleton 2003, Fingleton et al 2005, Ottaviano & Thisse 2004, Baldwin & Martin 2004). Externalities are inherently spatial, they are only to be found at certain locations, they are subject to distance decay and their effects are related to spatial densities of activity.

Agglomeration economies are positive externalities associated with spatial concentration of economic activity, resulting in lower marginal and average costs and increases in productivity. These are scale economies which do not apply at the level of the individual firm, but at the level of the industry. It is therefore possible to retain the assumption of perfect competition whilst analysing the effects of externalities.

It is usual to distinguish between locational economies, which arise from agglomeration of firms within the same industry and agglomeration or urban economies, which arise when firms in different industries agglomerate in the same (urban) area.

Externalities can be best understood by examining the case of locational economies in relation to the industry supply curve. A constant cost industry has a horizontal supply curve, which is derived from the minimum point on the long-run average cost (LRAC) curve of (identical) small firms in the industry. As the industry expands, new firms are added and the supply curve remains horizontal. If, however, there are scale economies which are external to the firm but internal to the industry, then the arrival of each additional firm will mean that the minimum point on the firms' LRAC curves will be lower and the industry LRAC and marginal cost curves slope down to the right, as shown in Figure 2.1. The supply curve of a declining cost industry becomes the LRAC curve rather than the marginal cost curve, as when price equals marginal cost, firms will make a loss. A further consequence is that an increase in demand (from D to D^1) for this type of industry will result in both lower prices and increased output, as shown in Figure 2.1, which is a prime reason for policymakers' interest in external scale economies. Urbanisation economies are related to the size of the local economy and in particular on positive effects, such as knowledge spillovers, between different industries. As noted in the literature, (Glaeser et al 1992, Engelstoft et al 2006) both localisation and urbanisation economies arise for a number of reasons including labour pooling, scale economies for intermediate inputs, development of ancillary trades and knowledge spillover effects. The microeconomic foundations of these economies are discussed in Duranton & Puga (2004) The theory of economies of agglomeration builds upon the assumption that downward sloping industry supply curves is a spatial (regional or urban) phenomenon. Thus, spatial proximity magnifies these effects and in many cases is a condition for their operation.

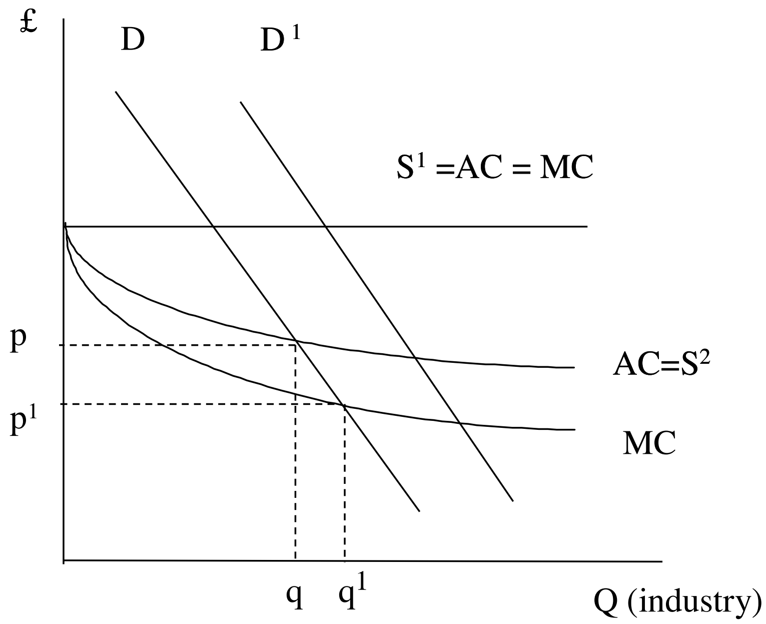

Fig. 2.1 Industry supply curves for a constant cost industry (S^1) and a declining cost industry (S^2).

2.2.1 Pecuniary and Technological Externalities

It is important to distinguish between the two types of externality, pecuniary and technological (Scitovsky 1952). These differences are illustrated here using the case of a change in the transport system which involves changes in transport costs. Pecuniary externalities arising from changes in transport costs have their origins in both the commodity and factor markets. Technological externalities have their origins in direct interactions, outside the market, between producers (p) and consumers (c), giving in all four different combinations (p-p, c-c, p-c and c-p).

Pecuniary externalities are illustrated in relation to the labour market in Figure 2.2.

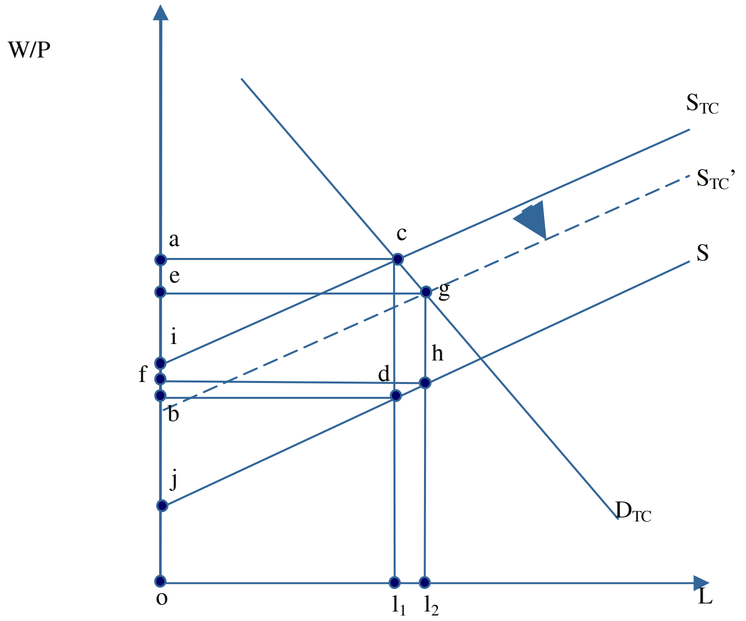

Fig. 2.2 Pecuniary externalities associated with transport system improvements.

Demand (D_{TC}) for and supply (S_{TC}) of labour are the standard curves which cross at equilibrium, c. Real wages both with and without transport costs, (TC) are shown in Figure 2.2. Seen from the viewpoint of the producer and the place of production, the demand for labour includes transport costs, D_{TC}. There are two supply curves for labour, S_{TC} which show labour supply in relation to the real wage (W/P) including transport costs (from the point of view of place of production) and S which shows labour supply in relation to the real wage (W/P from a place of residence point of view), net of transport costs from place of residence point of view. It can be assumed, that S is fixed in the long run, whereas S_{TC}, which includes transport costs, will shift with changes in these costs. In the case of transport system improvements the S_{TC} curve shifts to the right (S_{TC}'). This leads to a fall in equilibrium wage from a to e, a change in total wage bill from acl_1o to egl_2o and a change in expenditure on transport for commuting from acdb to eghf. How much demand for transport increases depends on the price elasticity of demand for and the supply of labour. The pecuniary externality effect for the producer is acge and for labour fhdb.

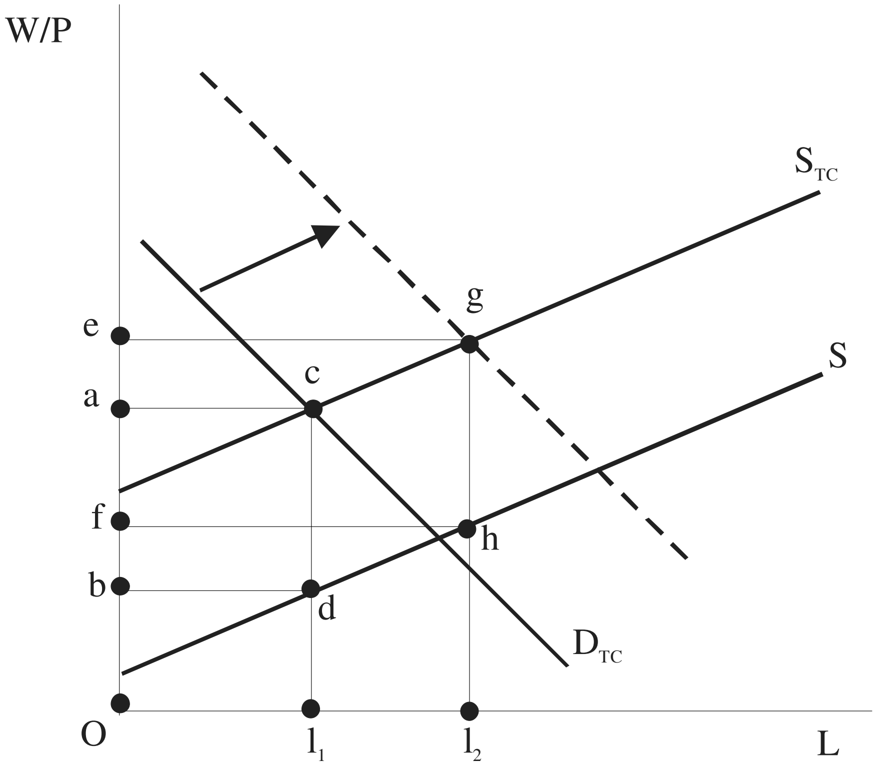

Fig. 2.3 Technological externalities associated with transport system improvements.

Corresponding externalities arising from changes in the transport system appear in the market for commodities, which can be illustrated in a figure similar to Figure 2.2. Equilibrium in the commodity market is established in market prices, including the cost of transport of commodities. The demand curve for commodities intersects with the supply curve at market prices. From the viewpoint of the producer, supply is determined in basic prices, net of transport costs. Supply in market prices is determined by the use of an adding-on principle. A transport system improvement will reduce transport costs and will shift the supply curve in market prices to the right. Equilibrium prices fall, which affects the real wage (W/P). Thus, a change in transport costs will affect both W and P as shown on the vertical axis of Figure 2.2. However, it is reasonable to assume that for any given decrease in transport costs, W will fall more rapidly than P because commuting costs are more important for labour than transport costs for commodity prices. In addition, the labour force is inherently regional, whilst commodities typically are produced in other regions or abroad, implying that the effect of local transport system improvements are greater for W than for P.

In the case of technological externalities, shown in Figure 2.3, demand for labour at a given real wage increases because of non-market interaction effects, including knowledge spillover effects (Audretsch & Feldman, 2000), arising from transactions undertaken by other agents. In this case of technological change, the demand curve for labour including transport costs (D_{TC}) shifts to the right, creating a new labour market equilibrium, as shown in Figure 2.3, moving from c to g. This means that demand for labour increases from l_1 to l_2 and the real wage increases from a to e. The wage bill increases from acl_1o to egl_2o. The change in total expenditure on transport is shown by cghd.

2.3 Proximity, Income and Externalities in Denmark

The previous section outlined a priori expectations concerning the relationship between changes in the transport system and externality effects in relation to the labour market. First, there will be a positive relationship between changes in transport costs and the level of real wages in the case of changes in accessibility in the labour and commodity markets, this being the effect of pecuniary externalities (Figure 2.2). Second, there is a negative relationship between changes in transport costs and changes in the level of real wages in the case of changes in accessibility to urban centres (Figure 2.3). This is the effect of urban (technological) externalities. The analysis also revealed that it is important to distinguish between the direct effects of externalities (which appear at the place of production and in the unit of production) and the end user effects, which appear in the institutions such as households, including the rest of the world, and at the place of residence of these institutions.

In this section, the results of an econometric study of real wages and externality effects in the Danish urban system are presented. In Section 5 an analysis of the redistribution of these effects to end users is presented, using the subregional model LINE, which is presented in Section 4.

2.3.1 Estimating Urban and Pecuniary Externality Effects: the Two Approaches

Two different approaches to analysis of the relationships between proximity, incomes and externalities are dealt with in the following. In order to estimate the effects of urban externalities the key spatial unit is the place of production, as the type of externality is production-production. In the case of pecuniary externalities, the spatial units of interest are both place of production and place of residence because demand and supply in the labour market involves these two components.

The first approach is based upon the hypothesis *that there is a positive externality affecting production associated with proximity to an urban centre* and that the externality is subject to distance decay. Distance is measured from place of production to an urban centre. The externality is on the production side and producers are able to pay higher wages because workers are more productive near the urban centre because of knowledge spillovers. Firms located near the centre also benefit from the externality. Different measures of distance to centres are employed, these being described below. The second approach is based upon the hypothesis *that commuting distance is positively related to wage levels.* Commuting distance is from place of residence to place of production which can be interpreted as a workplace disamenity and therefore workers require a higher wage if they have a longer commuting distance.

2.3.2 Factors Creating Differences in Wage Levels, Not Involving Externality Effects

In addition to distance, factors such as gender, age, education, and industry are often significant. Research confirms in the Danish case relationships between wage levels and age, education and gender(Albæk et al. 1999, Trigg and Madden 1995, and Berndt, 1991). If industry enters into the explanation, different sectors have different proportions of factor inputs (capital and labour) and may have better opportunities to exploit proximity advantages (cluster effects). The fact that wage levels are normally higher in the private sector (Berndt 1991), indicates that political decisions concerning production levels in the public sector are not based upon the wage equals the value of the marginal product principle.

2.3.3 The Data

The Social Accounting Matrix for Danish Municipalities (SAM-K) is the main data source in this study, and a complete description of the data is to be found in Madsen et al. (2001b) and Madsen & Jensen-Butler (2005). Two main sub-sets of SAM-K are used, the data having its origins in register-based individual level data, which are then grouped by variable.
Data used to estimate the *urban externality effects* has the following structure. The dependent variable is mean value of wages and salaries per person defined in relation to the categories used to group the individual values of the independent variables. Grouped data was used as data at individual

level was not available because of confidentiality requirements. The independent variables are principally category variables, representing, for each of the 275 municipalities, where place of production is located, grouped data. These data comprise age (3 groups), gender (2), educational qualification (5), industry (132), year (4) (to remove the effect of inflation on incomes). This gives 1,034,000 cells for each of the 4 years (275 x 3 x 2 x 5 x 132), in all 4,356.000 cells. 20.8% of these cells have non zero content with an average of 9.9 employees per observation In addition, there is a variable containing unemployment percentages for each age by sex by qualification by year for each municipality category (275 x 3 x 2 x 5 = 8.250 for each of the 4 years 33,000 possible different values). Finally, there is a distance variable, based upon location of the municipality, which has 275 possible different values. These distances are expressed as monetary values. Three different distance measures are used: i) to the urban centre in the (statistically defined) Danish labour market areas, ii) to the capital city Copenhagen, and iii) to the nearest of the five large university towns: Copenhagen, Århus, Odense, Aalborg, and Esbjerg. The dependent variable is mean value of wages and salaries per person (full-time equivalent) for each of the 66.000 cells for each of the 4 years.

Data used to estimate the *pecuniary externality effects* have the following structure. The dependent variable is mean value of wages and salaries per person defined in relation to the categories used to define the values of the independent variables. Grouped data were used as data at individual level were not available. The independent variables are principally category variables, representing, for each combination of the 275 municipalities where place of production is located and each of the municipalities where place of residence is located. In the data set used to estimate pecuniary externalities, it should be noted that basic data relates to groups of individual data by place of residence. These data comprise age (3 groups), sex (2), qualification (5), year (4) (to remove the effect of inflation on incomes). This gives 2,268,750 cells for each of the 4 years (275 x 275 x 3 x 2 x 5), in all 9,075,000 cells over the 4 years. This contrasts with data used to estimate urban externalities, where the basic data refers to individuals grouped by industry and there is no information concerning place of residence in this data set. In addition, there is a variable containing unemployment percentages by place of residence for each age by sex by qualification by year category (275 x 3 x 2 x 5 = 8,250 cells for each of the 4 years. Finally, there is a distance variable, based upon the 275 x 275 intermunicipality distance matrix. The dependent variable is mean value of wages and salaries per person (Full-time equivalent) for each of the 2,268,750 observations per year (= 275 x 275 x 3 x 2 x 5).

The number of observations is of course much smaller than the number of cells. Especially in the data set on pecuniary externalities the majority of cells are empty and a number of observations have been eliminated for different reasons.

The following observations have been eliminated from the data set used for the analysis of urban externalities: If place of work is abroad, not available, or located on the small island of Christiansø, and if age is below 15 or above 59. Furthermore, some extreme observations are removed, if the average wage is above 2 million DKK, and if total employment is under 5 working days in the year concerned. This all reduces the number of observations to 277,237 per year in the 4-year-period with an average of 9.0 employees per observation and a standard deviation of about 35 employees. About 1 per cent of the observations contain more than 100 employees. The highest number of employees in an observation is around 2,200. Similar reductions have been made for the data set used to analyse pecuniary externalities. The total number of observations here is 205,680 per year with an average of 9.9 employees per observation and a larger standard deviation of about 89 employees.

Different measures of distance are applied in the regressions, but the source is the same and distances are measured at municipal level. The distance from one municipality to another is the number of kilometres between the main post office in every pair of municipalities. An intra-municipality distance is calculated including elements such as size and shape of the municipality. When crossing water, kilometres are not an appropriate measure because there would usually be higher costs involved. Therefore, the kilometres are transformed into Danish kroner using the assumption that one kilometre on land equals one krone. When crossing water the price of a ferry ticket is applied instead of kilometres. The distances are calculated with base in 1996. The distances could be defined in other ways taking other factors into account such as congestion, speed limits, time values, etc., but more accurate distances are not used here.

2.3.4 The Effects of Urban Externalities

First, a real wage model with gender, education, sector, and unemployment as explanatory variables is set up and compared with a model which also includes municipalities as fixed effects. An F-test[1] cannot reject the hypothesis that the constant terms are all equal and therefore fixed effects are

1 See appendix B, I).

left out. In the fixed effects model with time dummies, unemployment is insignificant which corresponds to the results in Albæk et al. (1999).

Three measures of the centre are applied now in a model with gender, time, education, sector, and unemployment as explanatory variables. Fundamentally, more than one measure could enter into the model, but here it is assumed that there is only one type of centre in which one positive externality is present. Logarithmic transformation of all three measures describes the data better. Distance to the commuting centre is the worst measure compared with the two others because the adjusted R^2 is smallest comparing the three models which only differ with respect to the distance measure used. This might be because a definition of 35 commuting centres is chosen where some of the centres are small islands where no positive externality in production would be expected. The second best measure is the distance to Copenhagen. Given the geography of Denmark one would expect that it could be difficult to identify some distances because of the many belts, and straits.

Table 2.A.1 in appendix A contains the variable »distance5« this being the best of the three proposed measures. »Distance5« is the distance to one of the five university towns: Copenhagen, Århus, Odense, Aalborg, and Esbjerg. Whether or not to interpret it as distance to an economic centre or distance to a university city is a matter of choice.

The test described regarding heteroscedasticity[2] rejects the hypothesis that there is no heteroscedasticity in all three models with the explanatory variables of Table 2.A.1 in appendix A. The results of the FGLS regression are preferred to WLS and OLS because the t-value of β is numerically smaller in the heteroscedasticity test.

Because both the average wage and distances are in logarithmic form the estimated parameters are elasticities. However, the elasticity is small at -0.04. If an improvement in infrastructure could be interpreted as a shorter distance then a 10% improvement in infrastructure would result in a 0.4% higher wage. In the context of this study it is also a welfare gain because the higher wages are due to a positive externality.

Even though the elasticity is small the total welfare gain is worth calculating. In 1999 1.5 million workers had a place of work outside the 5 centres and their average wage was 260,000 DKK. If all distances outside the centres were reduced by 10% there would on average per worker be a welfare gain of 1040 DKK. The total welfare gain would be 1.5 million workers times 1040 DKK; a total of 1.560 billion DKK. ($1 = ca 6 DKK)

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[2] See appendix C, I).

When dealing with infrastructure investment the positive externality associated with a centre is not the only benefit. Therefore the total welfare gain of the positive externality should be calculated as one of the benefits.

When comparing the size of the estimates in the regression the most important contributions to the average wages are gender, education, certain sectors, and age. As mentioned the fixed effects model is rejected, which means that regional unemployment has a small but significant estimated parameter. An interpretation could be that higher unemployment lowers wages because of competition for vacancies.

2.3.5 Pecuniary Externalities: Wage Differentials and Commuting Distance

The second hypothesis is *that commuting distance affects wages*. To test this, a regression analysis on data set 2 is carried out.

Data set 2 has information about both place of residence and place of work. Both place of residence and place of work could be used as a fixed effect, but when comparing adjusted R^2, place of work is chosen. However, an F-test[3] does not support treating the municipalities as fixed effects and because of that they are abandoned.

The same problems concerning grouped data are present in this regression. The test described rejects the hypothesis that there is no heteroscedasticity[4] in all three models with the explanatory variables of Table 2.A.2 in appendix A. Again, the results of the FGLS regression are preferred to WLS and OLS because the t-value of β is numerically smaller in the heteroscedasticity test.

Gender, education, age, year, unemployment by place of residence and commuting distances are all significant in the model using FGLS, WLS, and OLS. Estimates and standard deviations are presented in appendix A, Table 2.A.2. Comparing the estimated parameter with the regression using data set 1, the estimated parameters of gender have increased by 17% (using FGLS) and other changes have also occurred. The estimated parameter of unemployment is still small, though it has increased. An explanation could be that unemployment by place of residence is used and in the regression using the first data set unemployment by place of work is used.

Commuting distance has a positive effect on wages. The estimated parameter is around 0.03 (using FGLS), which means that if commuting distance doubles the average wage would increase by 3%.

3 See appendix B, II).

4 See appendix C, II).

2.4. The LINE-Model - Modelling Externalities and Transport

Transport system changes have a *direct* impact on the costs of transportation, either by reducing transport costs as in the case of transport system improvements or by increasing transport costs as in the case of taxes on transport activities such as road pricing. Changes in transport costs have in turn direct effects on commodity prices and income: Transport cost changes influence directly the prices of commodities, because transport cost is a gross margin added to commodity trade. Transport costs are an addition to the price when shopping for commodities or when consuming as a tourist. In both cases the direct changes in transport costs are added to the price of the commodity after transportation to the buyer. Changes in transport costs also have a direct impact on disposable income net of commuting costs.

In addition, as discussed above, transport costs also have an influence on wage levels and productivity through the effects of pecuniary and technological externalities. These changes in transport costs have in turn direct effects on commodity prices and income. The effects derived from externalities add to the direct effects on the regional economy of changes in transport costs.

These direct effects on commodity prices and income, which now include the effects derived from externalities, lead to a number of derived effects on the regional economy. The distribution and magnitude of the total effects are, however, not the same as the distribution and magnitude of the direct effects (including the externality effects). The direct effects on commodity prices and income are redistributed through the interregional markets for commodities and production factors, through intra- and interregional trade, shopping and tourism, and through commuting and disposable income, assuming that price changes are transferred directly to the consumer. When prices and income change, the end user reacts by adjusting demand, which influences real economic activity. Therefore the derived effects (being the indirect and induced effects) should be added to the direct effects (including the externality effects) in order to estimate the total effects on regional economic activity.

In order to estimate these total effects, it is necessary to construct an interregional/subregional general equilibrium model. A subregional general equilibrium model includes the effects of changes in commodity prices and income arising from transport cost changes, including the externality effects, and also includes the real economic reactions to changes in prices and income. The reason for using an interregional general equilibrium model – and not just a national general equilibrium model- is twofold. First, the regional results are of importance. Second, modelling of the impacts on prices of changes in transport costs is a function of the regional pattern of interaction in the economy. A national model without a spatial dimension would not capture the changes in costs and prices derived from the spatial pattern of economic interaction.

In this section, an interregional/subregional general equilibrium model for Denmark, LINE, is briefly described. First, the real circle in LINE is presented which includes modelling the impacts of commodity price changes and changes in wages on real economic activity. This is followed by a presentation of the cost-price circle, which includes modelling of the changes in regional commodity prices and income. Finally, the inclusion of both pecuniary and technological externalities in LINE is considered.

2.4.1 LINE – an Interregional General Equilibrium Model for Modelling Redistribution of Productivity Changes

The full model and its equations are described in detail in Madsen et al. (2001a) and Madsen & Jensen-Butler (2004). The data used in the model, together with the interregional SAM, are described in Madsen & Jensen-Butler (2005) and Madsen et al (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. In the Keynesian circuit the well known effects from demand on supply and income and from income to demand are included. In the cost-price circuit the spillover and feedback effects of cost and price changes using an adding-up principle based upon the assumption of perfect competition are modelled. Figure 2.4 shows the general model structure, depicting the real circle employed in LINE.

The horizontal dimension is spatial: place of production (P), place of residence (R) and place of commodity market (S). Production activity is related to place of production. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of commodity market. The vertical dimension follows with its three-fold division the general structure of a SAM model. Production is related to activities (J); factor incomes are related to factors of production with labour classified by gender, age and education (G) and type of household (H), commodities are related to the supply and demand for commodities (I).

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in Figure 2.4. Starting in the upper left corner (PJ), production generates factor incomes[5] in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors (J) to gender, age and educational groups (G) and households (H) and from place of production (P) to place of residence (R) through a commuting model. Employment follows the same path. Employment and unemployment are determined at place of residence (R). In addition to other adjustments, taxes are deducted from factor income and transfers added, giving disposable income, which by definition is related to place of residence (RH)[6].

Disposable income is the basis for determination of private consumption in market prices, by place of residence (RH). Private consumption is divided into tourism (domestic and international) and local private consumption and assigned to place of commodity market (SI) using a shopping model for local private consumption and a travel model for domestic tourism. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities in market prices (SI). The market price variables are transformed into basic prices through a use matrix, including information on the commodity composition of demand and commodity tax rates and trade margin shares. In this transformation from market prices to basic prices commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production (SI). Through a trade model exports to other regions and production for the region itself is determined (PI). Adding export abroad, gross output by commodity is determined (PI). Through a reverse make matrix the cycle returns to production by sector (PJ).

Economic activity in the real circle is affected by changes in prices and wages: wages and productivity affect prices of the local production (PJ), which through relative changes in local competitiveness affects exports (PI) and imports (SI) which in turn affects private consumption through changes in real disposable income (RH). The anticlockwise cost/price circuit shown in Figure 2.5 corresponds to this dual problem. In the cost-price circle, production and demand are calculated in current prices, which in turn are transformed into relevant price indices. In the upper left corner production in current prices (in basic prices) is determined by costs (intermediate consumption, value added and indirect taxes, net in relation

[5] Factor income includes modelling different income concepts such as gross value added, GDP at factor cost and primary income.

[6] For simplicity in figures 4 and 5 modelling interactions inside the institutional sector between the household and governmental sectors, including taxes and subsidies, are not shown.

to production - PJ). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (PI). These are then transformed from place of production to place of demand (SI) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes. This transformation takes place using a reverse use matrix. Commodities for intermediate consumption enter into the next step in the production chain, determining prices of production and these prices are spread further in a round-by-round distribution process. Finally, private consumption is transformed from place of commodity market (SI) to place of residence in market prices (RI).

2.4.2 Direct Wage and Price Effects in LINE

As shown above, wages and prices will change as transport costs change. There are two direct effects, one which is truly direct, and one which arises through creation or reinforcement of externalities which in turn has an impact on prices. In Figure 2.5 the two types of direct effect on wages and prices are shown. The true direct effect is shown by an ellipse with dark shading, whilst the effects which operate through externalities are shown by an ellipse with lighter shading. The first effect enters directly into the price circle as an addition to costs and prices: In Figure 2.5 an increase in commuting costs implies that disposable income is reduced directly. In addition, commodity prices increase due to changes in transport costs for regional and interregional trade and also for changes in transport costs for shopping and tourism. The second effect works through externalities, both technological and pecuniary, which influence equilibrium wages and prices. In 2.5 a change in transport costs changes the size of the labour market and thereby the equilibrium wage. Changes in wages lead to changes in prices of production and in prices of commodities, following the logic of the cost-price circle. A change in transport costs will also affect the level of urban externalities and thereby wages and prices. This in turn changes the prices of commodities following the logic of the cost-price circle.

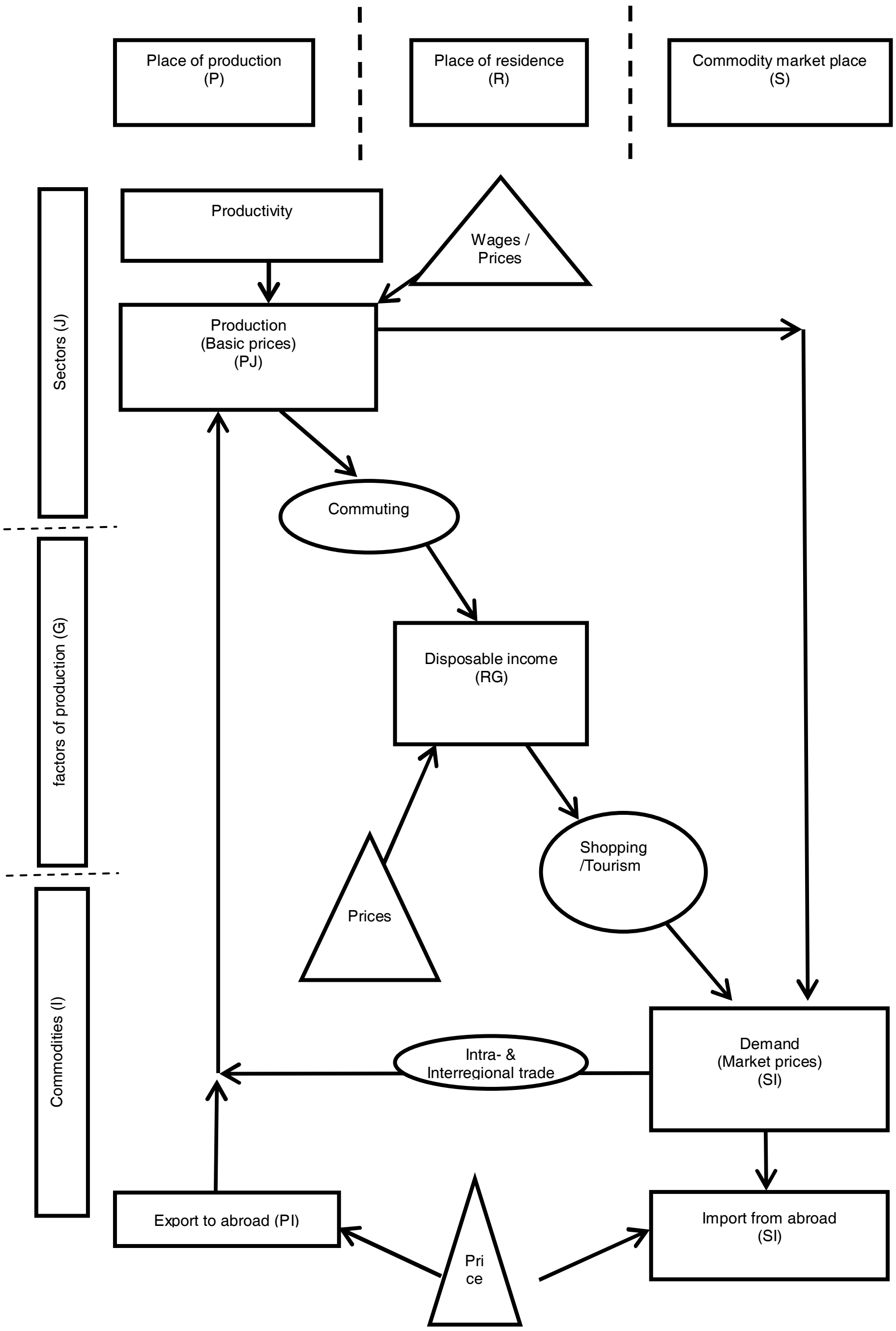

Fig. 2.4. The real circle in LINE – the impacts of price and wage changes on economic activity and behaviour.

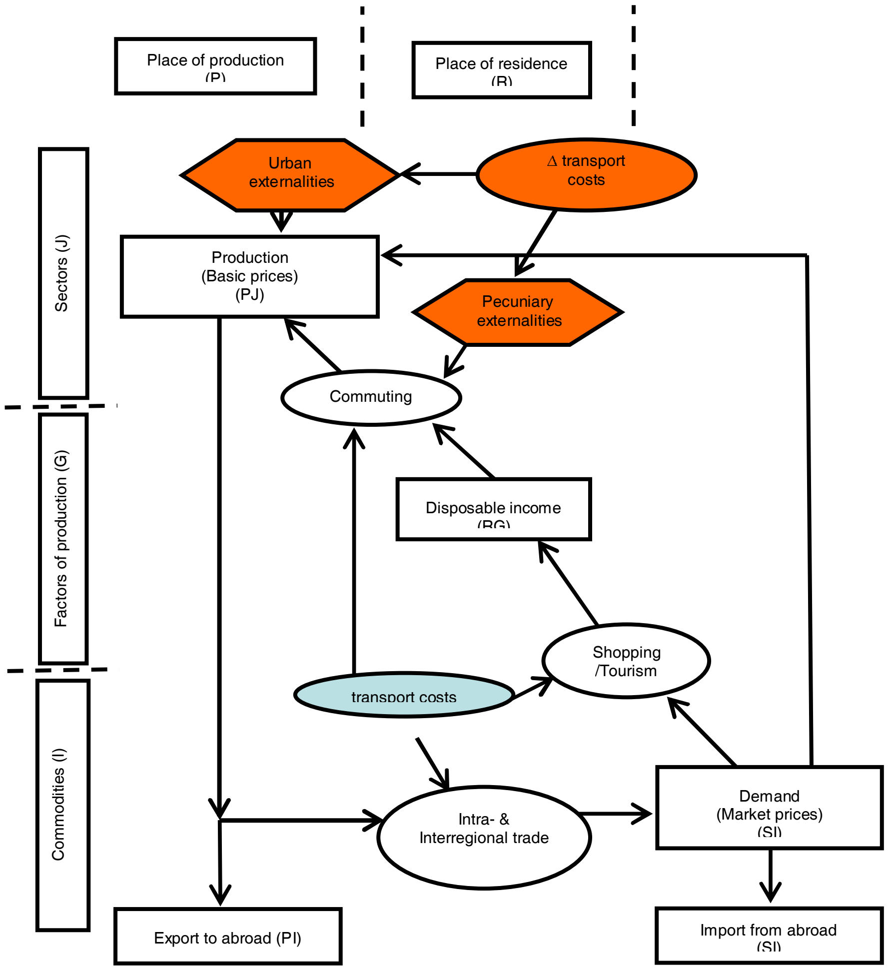

Fig.2.5 The cost-price circle in LINE. The impacts of transport cost changes on prices and wages.

It should be noted that this discussion and illustration of the effect of externalities is limited to the consequences of changes in transport costs for wages, as shown in Figure 2.5. Similar effects could be illustrated in relation to the commodity market, which have not yet been included in LINE.

The indirect and induced (derived) effects of wage and price changes depend in the medium term on exchange rate regimes. Foreign export and import prices enter into the determination of real foreign exports and imports at the regional level. If the economy is based upon fixed exchange rates, it matters whether or not a change in real wages leads to changes in nominal wages or changes in prices or a combination of these two. If wages change, assuming sticky prices, then competitiveness of domestic production is unchanged and the wage change will only have a minor impact on economic activity. On the other hand, if prices change, assuming sticky wages, then competitiveness of domestic production and international exports and imports will react with correspondingly more substantial effects on economic activity.

If the economy is based upon floating exchange rates, then changes in competitiveness due to changing prices will be more moderate as price changes will tend to be neutralised by exchange rate fluctuations.

2.4.3 LINE and SAM-K: Configuration

The data used in LINE is SAM-K, which is an interregional SAM. SAM-K can in principle be established at a very low level of spatial disaggregation, the level of the municipality, with 133 sectors and 2,850 commodities. For both theoretical and practical reasons SAM-K and LINE have been aggregated and reconfigured. Aggregate relations are, in general, more stable and robust. Also, working at an aggregate level makes fewer demands on computer capacity. The first question to be decided is which axes both in terms of geography and social accounting (SAM) should be used, and which should be aggregated away. The second question concerns the choice of aggregation of axes in the detailed database.

In this version of LINE the model configuration is the following.
Sectors (J):
21 sectors aggregated from the 133 sectors used in the national accounts.
Factors (G):
7 age, 2 gender and 5 qualification groups.
Households (H):
4 types, based upon household composition
Needs:
For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.
Commodities (I):
27 commodities, aggregated from 131 commodities used in the national accounts.
For SAM-K and LINE sectoral and commodity aggregations have been defined in relation to the transport focus in the analysis.

Regions:
277 municipalities, including one state-owned island and one unit for extra-regional activities, this being the lowest level of spatial disaggregation. Regions are defined either as place of production, place of residence or as place of commodity market. In this version of LINE the 277 municipalities have been aggregated into 16 regional units including one unit for extra-regional activities (see Figure 2.6).

It should be noted that the econometric analysis of proximity, income and externalities in Section 3 has been undertaken at a more detailed geographical level (municipalities) than the aggregation used in this modelling exercise, where counties have been used.

2.5 Modelling the Redistribution of the Relative Productivity Decline Associated with Road Pricing – the Case of Denmark

The main aim of this part of the analysis is to examine the consequences of including externalities in an analysis of the effects of a change in transport costs on regional economic activity. To demonstrate these effects, the hypothetical case of the introduction of road pricing in Denmark is examined. First, the road pricing scheme is presented, followed by a description of the way in which transport costs are affected. Second, the effects of transport costs on prices and costs with and without externalities are presented. Here the results of the estimation of urban and pecuniary externality effects have been applied. The total effects on real economic activity arising from changes in costs and prices divided into direct price effects and externality effects are estimated in Section 5.3. Finally, the methodological advantages of using an interregional general equilibrium model LINE, to analyse the national and regional impacts of road pricing – with and without externalities – are examined.

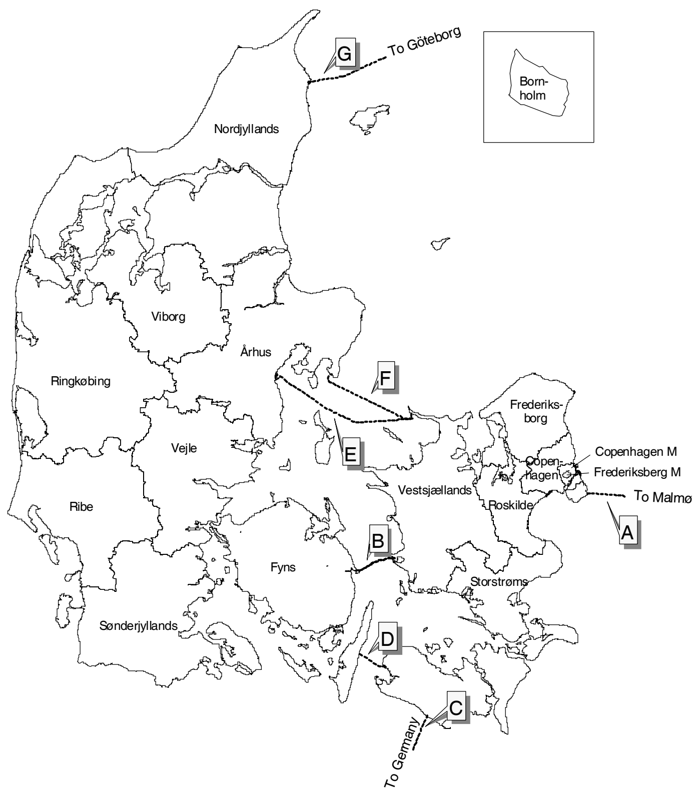

Fig. 2.6 Danish regions
Note: Danish regions are counties and two municipalities with county status, Copenhagen M and Frederiksberg M. Three fixed links: A: Oresund, to Malmo, Sweden, B: Great Belt, C: Femer Belt to Germany. Four ferry routes: D : Spodsbjerg-Taars, E: Odden-Aarhus (Mols Line), F: Odden-Ebeltoft (Mols Line), G: Frederikshavn-Gothenburg (Sweden). Other very local and international ferry routes are not shown.

2.5.1 Road Pricing and Changes in Transport Costs

The design of road pricing systems relates to general issues concerning transport policy and technical constraints and possibilities, in concrete institutional and cultural contexts. Road pricing systems are discussed in Jensen-Butler et al. (2005) and Madsen et al (2005). In this study it is assumed that a GPS-based/vehicle metered road pricing system is introduced throughout Denmark permitting precise identification of the location of a vehicle and thereby its road use, related in turn to toll level for the road. A range of different toll levels could be chosen, depending on type of vehicle, time of day, type of road, location, level of congestion etc. Here a simple assumption is made that tolls are set for cars only at DKK 0.6 per kilometre in urban areas and DKK 0.3 per kilometre in rural areas, on a 24 hour basis and irrespective of which type of road, car or level of congestion is involved.

Changes in transport costs are calculated using a) an interregional satellite account for transport used to determine *levels* of transport costs and b) exogenously given interregional transport costs, based on a digital road map**,** Vejnet DK, used to calculate *changes* in transport costs.

The data in the interregional satellite accounts are estimated in four steps:

a1) Taking the national make and use tables, national transport activity is determined by i) transport mode ii) subdivided by transport costs related to intermediate consumption (by sector) and to private consumption (by component) and iii) by external (transport firm based) and internal (own transport, within a non-transport producing firm or a household) costs. Six different modes of transport activity are used in the interregional satellite accounts, four for passenger transport and two for goods. Passenger transport is divided into car, rail, air and other and freight is divided into lorry and rail.

a2) In the second step national transport activity related to passenger transport is subdivided (using data from the National Travel Survey) by trip purpose: i) commuting ii) shopping, iii) tourism iv) business travel and v) recreation.

a3) National transport activity is then divided by origin and destination using data on intra and inter-regional trade (freight and business trip transport activity) and interregional shopping, tourism and commuting (personal trip transport activity)

a4) Regional transport activity is then corrected (using regionalised National Travel Survey data) to ensure that the data reflect regional transport activity by mode.

Changes in interregional transport activity for car transportation are estimated using the digital road map Vejnet DK. Transport costs in Vejnet DK are based upon both time and distance where the generalised cost has been calculated as time costs plus distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. In addition, costs are calculated both with and without road pricing. The calculations are based on assumptions shown in Table 2.1.

Table 2.1 Maximum speeds, distance and time costs, road pricing tariffs (DKK) (DKK 6=ca $1).

	Car	**Lorry**
Motorway	110 km/t	80 km/h
Non-urban highway	80 km/t	70 km/h
Urban	50 km/t or local restrictions taken from VejnetDK	Max 50 km/h or local restrictions if under 50 km/hour
Distance cost per kilometre	1.82 DKK	2.60 DKK
Time cost pr. Hour	0.75	2.78 DKK.
Road pricing – Urban	0.60	-
Road pricing – Rural	0.30	-

The estimation of level of transport activity by region, mode, purpose and by type of consumption described above reflects a basic assumption that data on transport activity obtained from National (transport satellite) Accounts used in a top down procedure, are superior to data on transport activity obtained from different statistical sources, used in a bottom-up approach.

In this chapter, only results involving road pricing for private cars is presented.

Table 2.2 shows the consequences of introducing road pricing for costs of transport between four representative type of region. Copenhagen and Frederiksberg are the core of the Metropolitan region, Vestsjœlland is the semi-rural hinterland of Greater Copenhagen, Sønderjylland is in the semi-rural periphery of Jutland and Aarhus is a free standing city in Jutland. The full table has 15 x 15 regions. It is assumed that all ferry routes and fixed links will continue with unchanged ticket prices. Transport costs in general increase from 2% to 13% outside the main cities of Copenhagen and Aarhus, least in the interregional links where use of rural roads is important or where a significant part of the journey uses ferries. In Copenhagen and Aarhus transport costs decline as road pricing results in a reduction of congestion, and thus, transport costs.

2.5.2 Effects of Transport Costs on Prices and Costs, With and Without Externalities

In this section the results of the changes in transport costs on costs and prices are presented. First, the results of a calculation without externality effects are shown in Table 2.3a. Then the consequences of including pecuniary externalities (Table 2.3b) and urban externalities (Table 2.3c) are presented. Results for four representative regions out of the 16 and the total changes are shown.

Table 2.2 Changes in total transport costs (index: 1.00 =unchanged) for transport between Danish regions after road pricing for cars.

(%)	CF	VS	SJ	AH
Copenhagen & Frederiksberg (CF)	0.91	1.06	1.07	1.01
Vestsjællands (VS)	1.06	1.12	1.08	1.00
Sønderjylland (SJ)	1.07	1.08	1.15	1.10
Aarhus (AH)	1.01	1.00	1.10	0.97

The analyses begin in the interaction components of the cost-price circle shown in Figure 2.5. In Tables 2.3a-c columns 1-10 reflect the cost price circle (Figure 2.5) moving anti-clockwise. Columns 1-3 show the impacts on production by sector and at the place of production (Cell PJ in Figure 2.5). Then impacts on commodity prices by commodity and by place of production are presented in columns 4-5 (cell PI in Figure 2.5). Continuing, columns 6-9 show the impacts by commodity and by place of commodity market (cell SI). Finally column 10 shows the impact on private consumption by commodity and by place of residence (cell RH in Figure 2.5).

Starting with the demand for commodities at the place of commodity market the prices of commodities increase in total by 0.05% (column 8), distributed regionally as indicated in the table. Prices increase most in rural areas of the country, whilst prices actually decline in Greater Copenhagen because of declining congestion.

Given the point at which the analysis commences, the presentation follows the cost-price circle: private consumption at the place of commodity market (column 9) and private consumption at the place of residence (column 10). Price increases are still moderate at the place of commodity market (at national level 0.04%), but markedly higher at the place of residence (at national level 0.42). This reflects the fact, that impact from cost increases on cars in trade is limited, because most transport on intra- and interregional trade typically is by lorry. But for shopping the transport cost increases from road pricing on cars are much higher, because private cars are used much more frequently for this purpose.

Looking at intermediate consumption, price increases are again moderate (column 2) reflecting the fact that most transportation related to intermediate consumption is by lorry, both in trade and in shopping (intermediate consumption from the wholesaler to the place of production). Therefore the impacts on the gross output deflator (column 3) and in turn on foreign export (column 5) are low. The regional distribution of changes in costs and prices are similar, for each column/regional economic variable, reflecting the fact that the direct impact of changes in transport costs reflect decreasing costs and prices in urban areas and increases in rural areas.

Examining the impacts from externalities, these are generated in a completely different way (see Table 2.3b and 2.3c): Here the impacts originate from changes in the Gross Value Added deflator (column 1) and then commence through the cost-price circle (column 2-10). Here the consequences for the price of production of all type of commodities are influenced through the wage impact. GVA In the case of pecuniary externalities (Table 2.3b, column 1) the GVA-deflator increases with 0.21% at the national level but only with 0.03% in the case of urban externalities (Table 2.3c, column 1). The regional pattern follows the one from changes in transport costs (Table 2.2). As a consequence all prices change accordingly. In this case there is no difference between the impacts on private consumption at the place of commodity market and the place of residence.

2.5.3 Effects on Real Economic Activity from Changes in Cost and Prices, With and Without Externalities

Real economic activity is influenced by the changes in prices. In addition, the way the revenues from road pricing is recycled, for example either through reduction in taxation or through increases in public consumption, will influence the level of economic activity. In this study only the gross impacts of cost and price changes are presented as the focus of the study is the multiplier effects of inclusion of externalities in the analysis. For a treatment of the public sector see Madsen et al (2005).

In this section the results of changes in real economic activity are described. First, the results of a model calculation without externality effects are shown in Table 2.4a. This is followed by an analysis of the consequences of inclusion of pecuniary externalities (Table 2.4b) and then of urban externalities (Table 2.4c). In Tables 2.4a-2.4c columns 1-10 reflect the real circle (see 2.4) moving clockwise. Columns 1-2 show the impacts on disposable income by place of residence (cell RH in Figure 2.4). In column 3 the impacts on private consumption by commodity and by place of residence (cell RI in Figure 2.4) are shown. In columns 4-7 the impacts on private consumption, local demand, foreign imports and demand for domestic production by place of commodity market (cell SI in Figure 2.4) are presented. Continuing in column 8 the impacts on foreign exports by commodity and by place of production are shown (cell PI in Figure 2.4). Finally, columns 9-10 show the impacts on gross output and GDP at factor prices by place of production (cell PJ in Figure 2.4).

The first step, where externality effects are not included, examines the impacts on disposable income and private consumption (Table 2.4a, column 1-4). Disposable income in current prices is reduced in average by 0.21% (column 1) because of the income reduction arising from road pricing on commuting. Second, real disposable income is reduced, because prices of private consumption increase. In total, real disposable income is reduced by 0.96% (column 2), which in turn reduces private consumption by 0.96% both at place of residence (column 3) and at place of commodity market (column 4). Demand is reduced, but proportionally less because the real impacts on other components of demand (intermediate consumption) is smaller or even unchanged (public consumption and investments). Exports to abroad are reduced because of increases in relative export prices (column 8). From this follows that gross output and GDP at factor prices are reduced (columns 9 and 10). From a regional perspective Copenhagen and Frederiksberg are scarcely affected whereas Sonderjylland and other parts of Jutland face high price increases resulting in a reduction in private consumption and exports.

When including the externality effects (see Tables 2.4b and 2.4c) there are two consequences, which have opposite signs: First, increases in income arising from wage increases related to road pricing (wage compensation), which increase private consumption and demand. Second, wage increases raise export prices and domestic prices which means that exports to abroad decline and imports from abroad increase, reducing domestic production. The second effect, based upon declining competitiveness dominates. The reduction in production will be even greater when including the externality effects.

The next step is to include pecuniary and technological externalities in the direct effects. The impact of these affects real wages, as shown above. The effects going from real wages to GVA are presented in column (1) of Table 2.4b (pecuniary externalities) and Table 2.4c (urban externalities). The effects are transmitted through the economic system in the same way as described in relation to Table 2.4a.

Table 2.5 shows the real economic consequences of both types of direct transport cost changes. The table shows the employment effect, which is closely related to changes in production, export, demand private consumption and disposable income. All these real effects have been derived from changes in costs and prices which influence demand: the total effect is a reduction in employment of 8423 when externalities are not included and 12654 when they are. Externalities add therefore approximately 50% to the pure direct effect on commodity prices and income.

2.6 Conclusions

In the study, an analysis on the impacts of changing transportation by introducing road pricing for cars in Denmark is presented. In the analysis, the impacts from externalities have been included, generating substantially higher gross effects of changing transport costs. The direct effects of changing transport costs on the labour market (pecuniary externalities or labour market enlargement effects) and on productivity (urban externalities through positive technological spillovers) are presented. The results of an econometric study in Denmark are presented. The derived effects were modelled using an interregional general equilibrium for Denmark, LINE.

The analysis shows that due to reduction in congestion the Greater Copenhagen area benefits through reduction in the transport costs, whereas rural areas suffer, because of long commuting distances. The total effects on employment are a reduction of approximately 8000 including the conventional commodity price and income reducing effects from road pricing and this reduction is approximately 4000 greater if externality effects are included. This demonstrates that conventional analysis is insufficient, because real impacts are underestimated. There is a need to include externality effects in analysis of transport system changes.

Table 2.3a Cost and price changes for production, demand, export, import and private consumption - without externalities

	(1) Supply: Gross Value Added (PJ)	(2) Intermediate consumption (PJ)	(3) Gross output (PJ)	(4) Gross output (PI)	(5) Foreign export (PI)	(6) Demand: Domestic production (SI)	(7) Foreign Import (SI)	(8) Demand (SI)	(9) Private consumption Place of market place (SI)	(10) Private consumption Place of residence (RH)
1	0.00	0.00	0.02	0.01	0.04	-0.02	0.00	-0.01	0.01	-0.13
2	0.00	0.08	0.11	0.10	0.25	0.10	-0.01	0.08	0.06	0.60
3	0.00	0.10	0.12	0.10	0.18	0.13	-0.01	0.10	0.08	0.77
4	0.00	0.05	0.06	0.04	0.11	0.05	0.01	0.04	0.03	-0.04
5	0.00	0.05	0.08	0.06	0.14	0.06	0.00	0.05	0.04	0.42

1. Copenh & Fredbg, 2. Vestsjælland, 3. Sønderjylland, 4. Aarhus

Appendix 2.A

Table 2.A1 Wage differentials by place of production. Estimated parameters and standard errors.

Dependent variable: ln(average wage)	FGLS	WLS	OLS
Intercept	12.04955 (0.00262)	12.07617 (0.00221)	12.0701 (0.00354)
Gender	0.17744 (0.00056923)	0.19182 (0.00042372)	0.15730 (0.00080864)
Year=1999	0.07181 (0.00086704)	0.06812 (0.00063209)	0.06648 (0.00124)
Year=1998	0.05261 (0.00083882)	0.05011 (0.00059852)	0.04885 (0.00121)
Year=1997	0.02129 (0.00078997)	0.01956 (0.00055930)	0.02116 (0.00114)
Long further and higher education	0.44529 (0.00116)	0.48476 (0.00089247)	0.38434 (0.00153)
Middle-range further and higher education.	0.32206 (0.00094904)	0.31477 (0.00069157)	0.29656 (0.00132)
Short further and hi. edu.	0.19079 (0.00102)	0.19089 (0.00084233)	0.16910 (0.00135)
Skilled worker	0.10002 (0.00065551)	0.10167 (0.00045153)	0.08367 (0.00098931)
Public and personal services	0.03522 (0.00158)	-0.00264 (0.00148)	0.08941 (0.00202)
Financial intermediation	0.19359 (0.00167)	0.19702 (0.00155)	0.19622 (0.00212)
Transport and communic.	0.09228 (0.00182)	0.11263 (0.00161)	0.08528 (0.00239)
Wholesale and retail trade	0.05271 (0.00164)	0.07839 (0.00150)	0.04573 (0.00213)
Construction	0.01555 (0.00207)	-0.00886 (0.00162)	0.03066 (0.00321)
Electricity, gas, & water.	0.15069 (0.00296)	0.10845 (0.00271)	0.17680 (0.00381)
Manufacturing	0.10046 (0.00158)	0.08810 (0.00148)	0.10430 (0.00201)
Age 45-59	0.26275 (0.00071966)	0.28820 (0.00053279)	0.22788 (0.00101)
Age 30-44	0.20693 (0.00070084)	0.22936 (0.00051082)	0.17211 (0.00099141)
ln(unemployment)	-0.02047(0.00081802)	-0.02993(0.00061965)	-0.02309 (0.00117)
ln(distance5)	-0.03893(0.00027692)	-0.04252(0.00017878)	-0.03165 (0.00045022)
* Adjusted R^2	-	-	0.215

Table 2.A2 Wage differentials and commuting distances. Estimated parameters and standard errors.

Dependent variable: ln(average wage)	FGLS	WLS	OLS
Intercept	11.99731 (0.00198)	11.96282 (0.00120)	11.95378 (0.00310)
Gender	0.20739 (0.00058077)	0.20313 (0.00032394)	0.18550 (0.00089959)
Year=1999	0.04847 (0.00088965)	0.6484 (0.00050635)	0.04807 (0.00137)
Year=1998	0.03423 (0.00086104)	0.04703(0.00048466)	0.03470 (0.00133)
Year=1997	0.01399 (0.00081145)	0.01898 (0.00045713)	0.01323 (0.00125)
Long further and higher education.	0.46169 (0.00109)	0.49915 (0.00071247)	0.45697 (0.00158)
Middle-range further and higher education.	0.29248 (0.00090276)	0.29033 (0.00055063)	0.30186 (0.00138)
Short further and higher education.	0.17716 (0.00101)	0.17132 (0.00068469)	0.19049 (0.00150)
Skilled worker	0.10374 (0.00070002)	0.09785 (0.00036837)	0.10002 (0.00111)
Age 45-59	0.30252 (0.00074048)	0.27874 (0.00042973)	0.31246 (0.00112)
Age 30-44	0.24254 (0.00071004)	0.22502 (0.00041411)	0.24134 (0.00106)
ln(unemployment)	-0.07263(0.00082992)	-0.03924(0.00047434)	-0.06847 (0.00130)
ln(distance)	0.03071 (0.00022535)	0.03067 (0.00016048)	0.04145 (0.00036696)
* Adjusted R^2	-	-	0.2626

Note Table 2.A1 and Table 2.A2: All variables are significant at 10% level. If all dummy variables are zero the representation is: Year=1996, basic education, and age 15-29 years old.

Appendix 2.B
F-test for fixed effects

F-test:

I) F-test in a model with wage differentials by place of production (data set 1) and explanatory variables gender, education, sector, age, and unemployment:
   As F (4,4) = 1 the hypothesis that all constant terms are equal could not be rejected.

II) F-test in a model with wage differentials (data set 2) and explanatory variables gender, education, age, unemployment, and commuting distance:
As F (4,4) = 1 the hypothesis that all constant terms are equal could not be rejected.

Appendix 2.C

I) A model with wage differentials by place of production (data set 1) and explanatory variables gender, time, education, sector, age, unemployment, and distance is examined. The squared residuals of the weighted regression (u^2) are estimated on the size of the group (N):

The results are:

	FGLS	WLS	OLS
$	0.01863	0.0060891	-0.00079502
t-value of $	26.89	36.53	-40.9

All of the t-values are significant and therefore a group error component could be present.

II) A model with wage differentials and explanatory variables gender, time, education, age, unemployment, and distance is examined.

The test described above gives the following results:

	FGLS	WLS	OLS
$	0.00461	0.00788	-0.00016861
t-value of $	9.84	329.21	-14.96

All of the t-values are significant and therefore a group error component could be present.

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Section 14:

Teleworking and Transport: Modelling the Regional Impacts in an Interregional General Equilibrium Model with Externalities

Bjarne Madsen, Arne Risa Hole, Chris Jensen-Butler, Morten Marott Larsen & Lasse Møller-Jensen

Section 14

Teleworking and Transport: Modelling the Regional Impacts in an Interregional General Equilibrium Model with Externalities

Bjarne Madsen, Arne Risa Hole, Chris Jensen-Butler, Morten Marott Larsen and Lasse Møller-Jensen

Abstract

In this section the regional economic impacts of teleworking are analysed. In this section teleworking is defined as home-based work at a distance from the usual place of work, using information and communication technology (ICT).

The impacts of teleworking have been analysed using AKF's local economic model LINE and include the impacts on regional production, income and employment. LINE is an interregional general equilibrium model, which uses an interregional social accounting matrix (SAM-K) and a regional transport satellite account as the basis for modelling. Additionally, data from a transport survey from Statistics Denmark have been included to estimate the frequency of teleworking.

In the working paper the consequences of teleworking have been subdivided into 3 components: 1) The demand effects of increasing income net of commuting of reducing transport cost by introduction of teleworking, 2) the labour enlargement effect reducing wages through reduction in commuting cost and 3) the productivity effects of introducing teleworking as an alternative production technology compared to production at place of work.

In total the impacts of teleworking are very limited. Relatively, regions with high level of income, education and long working weeks and with long commuting distances attain the highest gains, because in these areas the share of teleworkers is at its maximum.

1. Introduction

Teleworking, or work at a distance from the usual place of work, using information and communication technology (ICT) is a type of behaviour which is attracting increasing interest from researchers and policy-makers alike. The ICT revolution has opened a range of new possibilities of organisation of work arising from the fundamental technological change. This paper explores the principal consequences of the growth of teleworking, both for households and producers. Teleworking can be understood as a consumption choice by the individual, when faced with a number of alternatives which provide access to the workplace. It can be regarded as a substitute for commuting, which in turn can be undertaken by one of a number of transport modes (for example car, train, bicycle, walking). The various transport modes have, like telework, varying levels of utility for the commuter. The main effect for households is time savings in relation to transport, savings which can be allocated to other uses with higher utility.

Producers can also have an interest in the level of teleworking. Teleworking seems to have a positive effect on productivity as households' available time for production increases and workers' transport costs decrease. In addition, cost reductions through economies in the use of space and equipment can occur. Teleworking is also associated with organisational change and process innovation. On the other hand, some degree of control over the labour force by the owner of the firm or manager of the organisation is lost. In addition, there is a further positive effect associated with an increase in the size of the potential labour market for firms, which is a pecuniary externality.

However, much of the interest in teleworking has been generated because of its assumed positive externality effects on congestion and environment. These arise essentially from the assumption that teleworking is a substitute for travel to work, and as such reduces both congestion and emissions to the environment, associated primarily with the transport sector. These effects are the principal reason for the substantial growth in interest in teleworking shown by both policy-makers and politicians (NUTEK 1998).

This study addresses the economic consequences of teleworking seen in a regional context. These are examined in terms of the direct effects on both households' utility and firms' production using an interregional general equilibrium model. LINE the regional impacts of the direct and derived effects are identified and illustrated in the case of Denmark.

2. Teleworking: Definition and extent

There is no simple operational definition of teleworking as it can include a range of work-related activities, such as home-based work using ICT, work at home using ICT whilst having a permanent place of work elsewhere, work in telecentres and work using mobile telephony with internet access. Of course, not all work at home is telework and some people no longer have a fixed workplace outside the home which is their own. Vilhelmson & Thulin (2001) define teleworkers as employed persons, who use ICT for regular work (at some unspecified interval), which is done at a location other than the ordinary fixed place of work. A similar, but narrower definition is adopted here, where the use of ICT for full time or part time work is home-based, and the prime interest is the worker who substitutes between commuting (between home and place of work) and teleworking. This definition excludes mobile teleworking and work in telecentres. Such a restrictive definition is necessary for practical reasons, as problems of definition and data collection otherwise would become very serious.

Millard et al. (2005), using data from two Danish sources provide the following estimates of teleworking in Denmark:

Table 1. Estimates of teleworking[1] as share of employment in Denmark in 2002

			Share of work
Work location: home, with place of work elsewhere	Teleworking	Full time on teleworking day	3.3%
		Part time on teleworking day	3.6%
		Total	6.9%
	Non-tele-working	Full time	2.1%
		Part time	4.4%
		Total	6.5%
Work location: home, without place of work elsewhere			4.2%
Work location: place of work with commuting			82.4%
Total			100%

Source: Millard et al. (2005) and Statistics Denmark, Transport Habit Survey (Transportvaneundersøgelsen)

[1] A teleworker is defined as a person who has practiced teleworking at least once during the last month.

The table shows, that according to this estimate 6.9% of employed people telework at least part time and 3.3% telework full time. This figure is similar to the share of employed people, who work at home without telework. From these figures it is not possible to calculate the number of employed people, who telework on any given day.

Estimates of the extent of teleworking in western countries show similar results. NERA (2000) provides an estimate that 1998 levels of teleworking were between 0.5 and 5.0% of the

UK working population and that on any one weekday 0.1 to 1.0% of the UK working population are actually engaged in teleworking. Vilhelmson & Thulin (2001) estimate that about 5% of all employed persons in Sweden in 1999 were regularly engaged in telework and about 2% were actually engaged in this activity on any one weekday. Vilhelmson & Thulin (2001) estimates, that 4.8% of all employed persons in Sweden in 2000 are teleworkers (teleworking at some unspecified interval). In the Netherlands De Graaff & Rietveld (2004) estimates that the actual share of teleworking do not exceed 3-4% of the labour force.

The study of teleworking is difficult, as small numbers in large populations are involved, and there is no obvious stratification criterion, thus, the problems of collecting data on teleworking are substantial. Together with the problems of definition of teleworking, it is easy to understand the considerable variation in estimates of levels of teleworking between different studies.

3. The direct impacts of teleworking

In this section a theoretical analysis of the direct effects of telework is presented. This framework is then in the following sections used in interregional general equilibrium models to examine the full regional economic effects, both direct and derived, of changes in the intensity of teleworking.

The prime interest is to examine the effects of the growth of teleworking on the economy in terms of changes in income and employment and the regional distribution of these effects. Teleworking affects the labour market, increasing the supply of labour at any given wage level. At the same time teleworking transforms the production process, changing the location of production, at least partially from place of work to residence. Both aspects influence the costs of production and price of commodities. This represents a supply-side approach to evaluation of impacts of teleworking. This means that an accounting approach to evaluation of impacts of ICT on economic activity (for example using National Accounts data on sectoral GDP or employment in the ICT sector or data from Satellite Accounts) would lead to erroneous conclusions about the economic importance of the sector. Instead, the impacts must be evaluated using a modelling approach involving changes in cost and prices, which necessitate the use of the general equilibrium approach to modelling.

In this approach a distinction is made between the direct and the derived effects of the growth of teleworking. The derived effects include redistribution between regions and actors as well as the overall multiplicator effects, both indirect and induced.

Two direct effects of teleworking on the regional economy can be identified. First, teleworking reduces commuting costs, which in turn creates two separate effects: 1a) There is a direct impact on costs of commuting. If for example 2% of the population telework on average 4 days a month then the total monthly transport cost of commuting is reduced by about 0.4% (0.02 x 4 days / 20 days). This will increase the household disposable income (after commuting costs). 1b) The reduction in transport cost has in turn a direct impact on the labour market, as the labour supply curve shifts to the right, which implies a reduction in wage level, as the geographical extent of the labour market increases.

Second, teleworking probably has a positive effect on labour productivity. This reflects the fact that the total product associated with production in the home increases to a maximum because a number of factors facilitate the working process at home compared with the working process at work: The time saved on transport between home and work is partially allocated to working time. The disturbances of the production process at place of work might be reduced substantially by relocating production activities to the home. On the other hand new disturbances related to home production can potentially reduce productivity. Finally, positive externalities from contact with colleagues might be lost if the volume of telework is too high.

These three direct effects of teleworking affect different actors and different locations in the regional economy: 1a) The transport cost reduction directly affects commuting costs, where earned income by (labour) factor group – before transport costs are deducted – is transformed from the place of production to the place of residence; 1b) in a similar manner, the wage rate affects place of production, place of residence and (labour) factor group in relation to factor markets; 2) finally, the productivity effects affect place of production, industry and (labour) factor group. These three direct effects are discussed in more detail in the following three sections.

3.1 Disposable income, teleworking and commuting costs

Disposable income net of commuting costs is higher when teleworking is undertaken. In order to calculate the savings in transport costs arising from telework it is necessary to estimate the share of teleworkers in employment by region and the intensity of teleworking, given that a person is a teleworker. In principle, if data were available, an accounts-based approach could be used to obtain these estimates. However, limitations on data availability related to sample size and the limited number of observations related to teleworkers in the official statistics suggest that a data modelling approach is more reliable. The take-up of teleworking is modelled using data from the Transport Habit Survey (Transportvaneundersøgelsen) 2002-2003, collected by Statistics Denmark, which provides representative information about the composition, characteristics and travel behaviour of Danish households. The data contain information on whether or not the respondents sometimes telework and how often, as well as a range of relevant possible causal variables. These variables fall into three broad groups: i) the characteristics of the teleworkers themselves, ii) the characteristics of the work performed by the teleworker and iii) the spatial characteristics of the teleworking relationship.

The variables which are associated with the decision to telework have been identified using a binomial logit model (table 1). Respondents with relatively high levels of income are found to be more likely to telework than those with low incomes, although the likelihood of teleworking declines with very high incomes (as reflected by the negative and significant coefficient for income squared). Moreover, respondents with a relatively high level of education are more likely to telework than those with no education above compulsory school level. Respondents living in a household with children in the age group 5-9 are more likely to telework than those living in a household with no children in this age group. Also, respondents living in a household with high levels of car ownership relative to the number of workers are more likely to telework than those living in a household with a relatively low car ownership to worker ratio. Furthermore, commuting distance, as well as the average length of the working week, is found to have a positive and significant influence on the propensity to undertake telework. Age, gender, household type and whether the respondent works in the private or public sector were not found to have a significant influence on teleworking propensity at the 5% significance level.

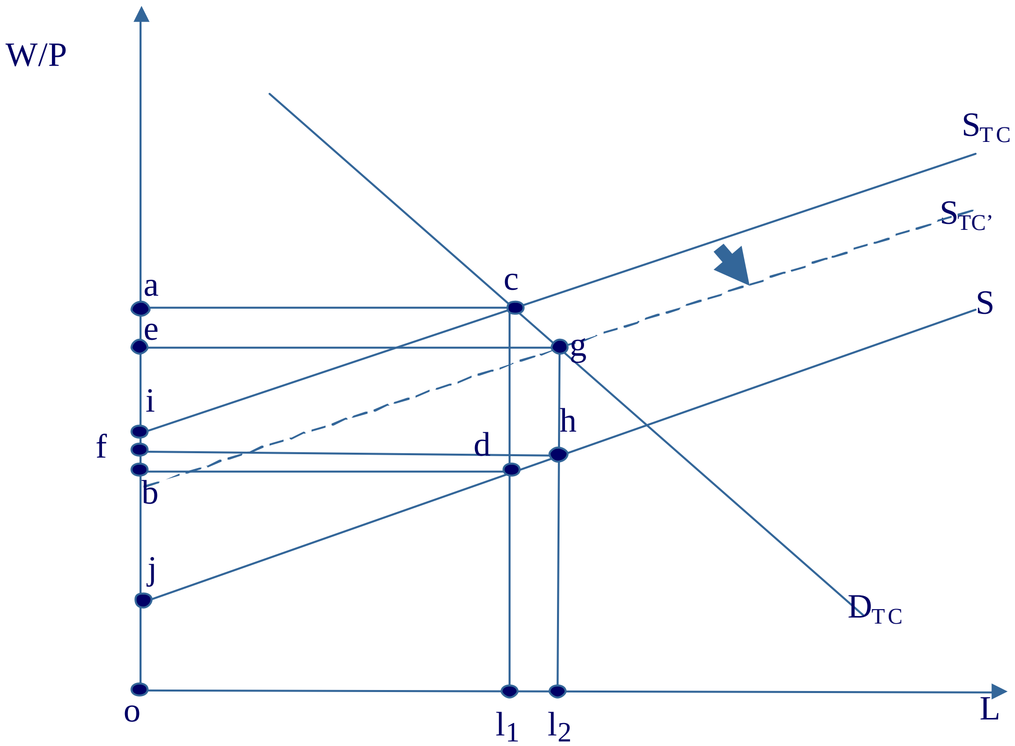
The second step transforms the number of teleworkers to the number of full-time equivalent (fte) teleworkers. Using another dataset based on a sample of Danish internet users (Hole et al. (2004), see also section 3.3) the average number of telework days per month was estimated. This estimate was used to estimate the number of full-time equivalent teleworkers.

3.2 Wage levels, pecuniary externalities and teleworking

As described above, wages and prices will change as transport costs change. There are two direct effects, one which is truly direct (see section 3.1), and one which arises through creation or reinforcement of pecuniary externalities in the labour market which in turn have an impact on commodity prices. The theoretical foundation of this hypothesis is labour-market externalities. If accessibility increases through a reduction in transport costs, the geographical extent of the labour market will increase, and then because of the theory of compensated wage differentials[1], which indicates that wages paid to workers should compensate for or equalise differences in workplace amenities and disamenities, the wages will decrease. Both monetary differences and also non-monetary advantages are reflected in the wage.

Pecuniary externalities can be illustrated in relation to the factor market in figure 1.

Figure 1. Pecuniary externalities in the labour market



Demand (D_{TC}) for and supply (S_{TC}) of labour (including transport costs, TC) are the standard curves which cross at equilibrium, c. Seen from the viewpoint of the producer, the demand for labour includes transport costs, D_{TC}, this being from the point of view of the place of production. Labour has two supply curves, S_{TC} which is the real wage including transport costs (from the point of view of place of production) and S which is the real wage (from a place of residence point of view), net of transport costs. Under certain assumptions, one can assume that S is fixed in the long run, whereas (S_{TC}), which includes transport costs, can shift because of changes in these costs (the add-on assumption). An example of such a change is growth in teleworking. The diagram can be used to illustrate the impact on wage levels and demand for transport, of growth in teleworking (or transport-system improvements in general). Assuming that the S curve is fixed, a growth in teleworking will shift the S_{TC} curve to the right (S_{TC}'). This leads to a fall in the equilibrium wage from a to e, a change in total wage bill from acl$_1$o to egl$_2$o and a change in expenditure on transport for commuting from acdb to eghf. Whether demand for transport increases or decreases depends on the price elasticity of demand for transport and the elasticity of demand for labour.

1 Brown (1980).

Transport costs must therefore be included in an econometric analysis of determinants of wage levels. In this study commuting distance is used as a proxy for transport cost. However, in addition to transport costs, factors such as gender, age, education, and industry are often significant (Berndt 1991). In the Danish case research confirms the relationships between wage levels on the one hand and age, education and gender on the other (Albæk et al. 1999, Trigg & Madden 1995). If industry enters into the explanation, different sectors have different proportions of factor inputs (capital and labour) and may have better opportunities to exploit proximity advantages (cluster effects).

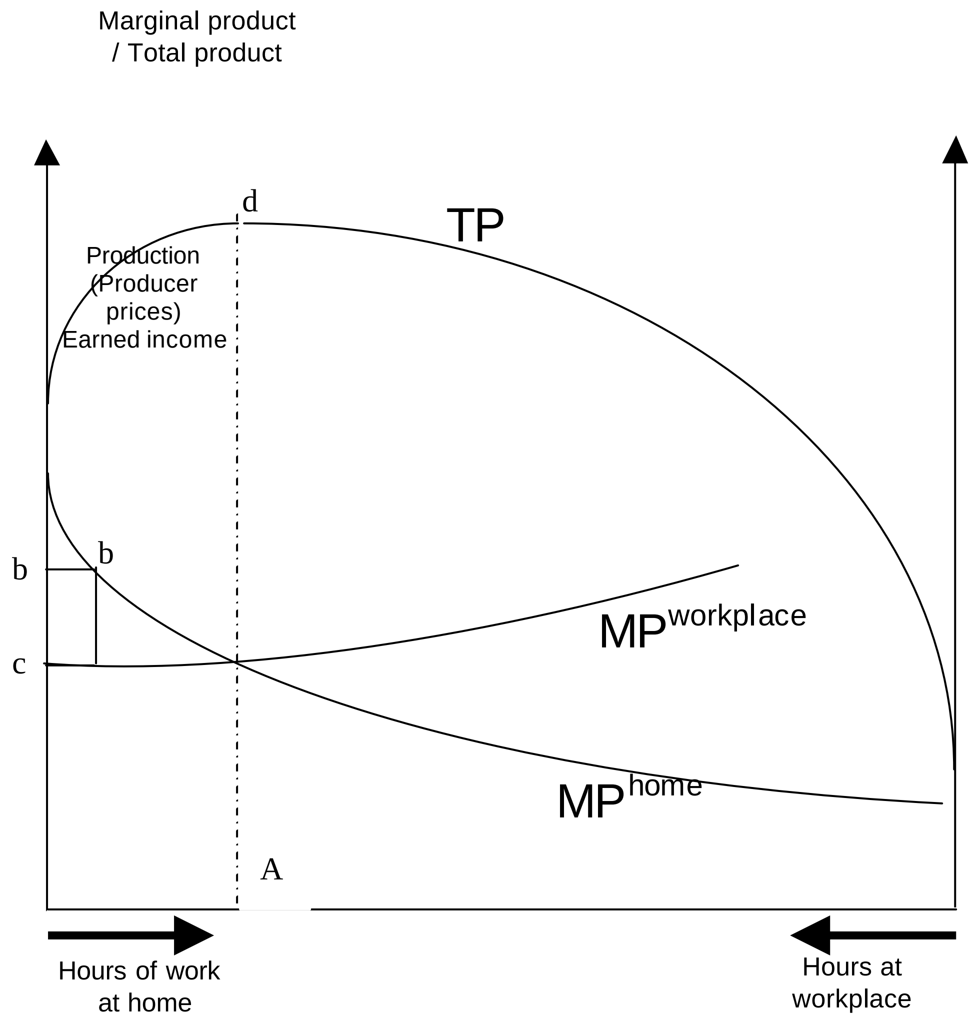
Danish data used to estimate these *pecuniary externality effects* have the following structure. The dependent variable is mean value of wages and salaries per person defined in relation to the categories used to define the values of the independent variables. Grouped data were used as data at individual level were available. The independent variables are principally category variables, representing, for each combination of the 275 municipalities where place of production is located and each of the same municipalities where place of residence is located, grouped data. These data comprise age (3 groups), gender (2), qualification (5), year (4) (to remove the effect of inflation on incomes). This gives 2,268,750 cells for each of the 4 years (275 x 275 x 3 x 2 x 5), in all 9,075,000 cells over the 4 years. In addition, there is a variable containing unemployment percentages by place of residence for each age by gender by qualification by year category 275 x 3 x 2 x 5 = 8250 cells for each of the 4 years. Finally, there is a distance variable, based upon the 275 x 275 intermunicipality distance matrix. The dependent variable is mean value of wages and salaries per person measured as full-time equivalents for each of the 2,268,750 cells per year. There are data in 908,947 cells over the 4 years corresponding to about 10% of the cells, each containing on average 9.0 workers.

The regression equation was estimated using OLS, WLS and GLS, as OLS is generally considered as inappropriate for use with grouped data. The estimates obtained from all 3 estimation methods were consistent with each other, though GLS was chosen as the best estimator. These results are to be found in appendix 1. The results show that gender, education, age, year, unemployment by place of residence and commuting distances are all significant. Commuting distance has a positive effect on wages. The estimated parameter is around 0.03. With an elasticity of 0.03 one would get 3% more in average wage if the commuting distance doubles.

3.3 Labour productivity and teleworking

As described in the introduction, teleworking probably has a positive effect on labour productivity, this theoretical assumption being based upon conventional theory of production involving diminishing returns and the choice of combination of alternative technologies, in which case technologies are applied until the point at which their marginal products are equal as shown in figure 2.

Figure 2. Marginal product and total product working at place of residence (teleworking) and place of work



The total product is inverted U-shaped, as shown by TP in the figure. Total production (TP) increases with an increasing share of teleworking and reaches a maximum at point A, after which any further increase in teleworking will reduce TP. This reflects the nature of the two marginal product curves for the two technologies: production at home (MP^{home}) and production at workplace ($MP^{workplace}$). It should be remembered that the $MP^{workplace}$ curve should be read from right to left. The MP^{home} curve declines as the intensity of teleworking grows, reflecting the fact that the incremental benefits of teleworking decrease with its increasing use. The incremental benefits of work at place of work also decrease as hours spent at the workplace grow. The decline in MP^{home} occurs for a number of reasons discussed below. The time saved on transport between home and work is partially allocated to working time together with higher production of homework compared with work at the place of work, which in figure 2 is represented by the difference b-c. This of course applies only to industries where teleworking is feasible. If this is not the case the MP^{home} curve will lie below the $MP^{workplace}$ curve for all amounts of teleworking. Where teleworking is feasible, the MP^{home} curve lies over the $MP^{workplace}$ curve for the first day of teleworking, but the difference declines as the number of teleworking days increases and becomes negative as teleworking grows beyond point d. The shape of the MP^{home} and the $MP^{workplace}$ curves can be explained by diminishing returns in each case. In the teleworking case, lack of interaction with colleagues will reduce benefits of co-operation and learning processes based upon interaction. In addition, reduction in levels of interaction with colleagues will reduce the rate of creation of process innovations. In the $MP^{workplace}$ case, increases in time spent at the place of work will reduce the incremental benefits of interaction with colleagues as well as increasing tiredness and exhaustion. Total product is maximised (at point d) where the marginal products of the two technologies are equal, which is a standard result.

This theoretical result has been tested using data from a sample of Danish internet users (see Hole et al. 2004) in which a subset of the respondents was asked to state their productivity the last time they teleworked relative to their productivity working at their workplace (in per cent). Using an OLS model, the reported productivity has been regressed on several explanatory variables, including the intensity of telework as well as socio-demographic variables such as age, gender, education, size of residence and whether the residence has a dedicated room for teleworking as well as commuting distance. The estimates of the regression coefficients provided by this regression and heteroscedasticity-consistent standard errors are shown in table 2.

Table 2. Productivity of telework vs. work undertaken at the workplace

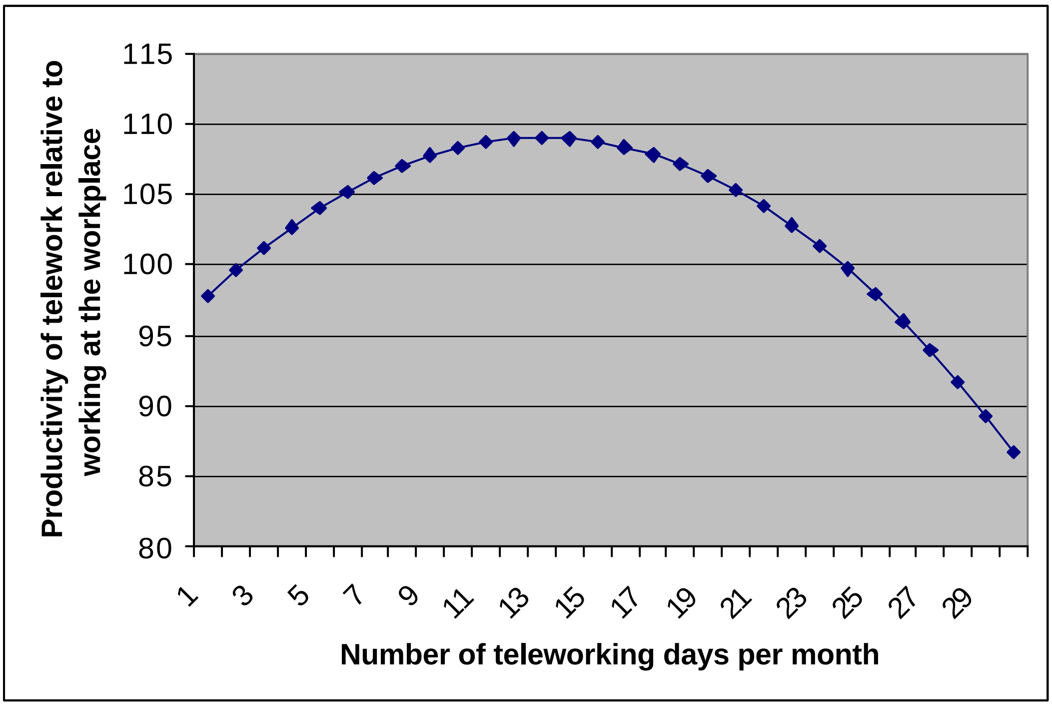
Variable	Coefficient	Std. error
Constant	92.803	7.09
Female	2.945	2.92
Age (ref. under 30)		
31-40	-1.000	4.49
41-50	2.399	4.65
Over 50	-2.267	5.81
Education above compulsory school level	5.721	4.97
Dedicated room for telework in residence	1.255	3.27
Size of residence (sqm)	0.0185	0.02
Distance to work (km)	0.0185	0.04
Number of teleworking days in the last month	2.019*	0.73
Number of teleworking days in the last month squared	-0.077*	0.03
Sample size	354	
R^2	0.04	

* Denotes significance at the 5% level

It is interesting that the only coefficients in the regression equation at the 5% level are those related to the intensity of telework as measured by the number of teleworking days per month and its square. While the intensity coefficient has a positive sign, indicating that the productivity of telework increases in its intensity, the sign of the coefficient for the square of teleworking intensity is negative. Together this implies that the relationship between the productivity of telework and its intensity is inversely U-shaped as indicated by the theoretical model. Figure 3 shows the graph of the relationship for a representative individual.[2]

2 The curve is calculated using the sample average residence size (140.5 sqm) and commuting distance (23.2 km) and setting all the dummy variables to zero (this implies a male, below 30 years of age, with no education above compulsory school level and without a dedicated room for teleworking).

Figure 3. The relationship between the productivity of telework and its intensity



The productivity curve peaks at 13 teleworking days per month, implying that the current situation is not optimal as the average number of teleworking days per month in the sample is 7.3. Since this sample only includes individuals who sometimes telework, the average number of teleworking days per month among all workers is likely to be substantially lower. This raises the question why workers do not work at home more frequently, given that an increase in the number of teleworking days would entail a gain in productivity for most workers according to these empirical results. The likely answer is that various restrictions on teleworking are imposed by the employer. Many workers, of course, are not able to telework at all due to technological restrictions. In addition, there may be other cultural and institutional restrictions on teleworking, such as fear of being characterised as being lazy by other workers.

Using the results from the analysis above the effect on productivity of a reduction of the frequency of teleworking can be calculated. For example, if teleworking was abandoned altogether productivity will decline by about 3.2% per month on average among former teleworkers, assuming that they work 20 days per month (0.087 x 7.3 days / 20 days). It follows that the reduction in teleworking days would lead to an overall 0.16% loss in productivity per month assuming that the total share of teleworkers is 5% (0.032 x 0.05).

4. Modelling-derived regional economic effects of teleworking – the LINE-model

Teleworking has a direct impact on the cost of transportation, either by reducing transport cost as in the case of future growth in teleworking or by increasing transport costs as in the case of abandoning teleworking. Changes in transport costs have a direct impact on income disposable income after commuting costs are deducted if transport costs change. Additionally, as discussed in section 3.2, transport costs also have an influence on wage levels through the effects of pecuniary externalities. These effects derived from externalities add to the direct effects of transport cost changes on the regional economy. Finally, the direct impact on productivity from shifting between technologies: production at home and production at workplace (section 3.3).

These direct effects on income and commodity prices lead to a number of derived effects on the regional economy. The distribution and size of the total effects are, however, not the same as the distribution and size of the direct effects (including the externality and productivity effects). The direct effects on income and commodity prices are redistributed through the interregional markets for production factors and commodities, through commuting and disposable income and through intra- and interregional trade, shopping and tourism. This assumes, given perfect competition, that price changes are transferred directly to the consumer. When price and income change, the end user reacts by adjusting demand, which influences real economic activity. Therefore the indirect and induced effects should be added to the direct effects (including the externality and productivity effects) in order to estimate the total effects on regional economic activity.

In order to estimate the total effects, it is necessary to use an interregional/subregional general equilibrium model. A subregional general equilibrium model must include the modelling of changes in income and commodity prices due to transport cost changes, including the externality and productivity effects and must also include the real economic reactions to changes in income and prices. In this section, an interregional/subregional general equilibrium model for Denmark, LINE, is briefly described. First, the real circle in LINE is presented. This includes modelling the impacts of changes in wages and commodity price changes on real economic activity. This is followed by a presentation of the cost-price circle, which includes modelling of the changes in regional commodity income and prices. Finally, the inclusion of both pecuniary externalities and productivity effects in LINE is considered.

4.1 LINE – an interregional general equilibrium model for modelling redistribution of productivity changes

Here a brief graphical presentation of LINE is made. The full model and its equations are described in detail in Madsen et al. (2001a) and Madsen & Jensen-Butler (2004). The data used in the model, together with the interregional SAM, are described in Madsen & Jensen-Butler (2004) and Madsen et al. (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. Figure 4 shows the general model structure, based upon the real circle employed in LINE.

The horizontal dimension is spatial: place of work (R), place of residence (T) and place of commodity market place (S). Production activity is related to place of work. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of commodity market. The vertical dimension follows with its three-fold division the general structure of a SAM model. Production is related to activities; factor incomes are related to i) activities by sector (E) ii) factors of production with labour by gender, age and education (G) and iii) demand for commodities (V).

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in figure 4. Starting in the upper left corner (cell (RE)), production generates factor incomes in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors to gender, age and educational groups and from place of production to place of residence through a commuting model (from cell RE to cell RG). Employment follows the same path. Employment and unemployment are determined at place of residence (cell TG). In addition to other adjustments, commuting transport cost and taxes are deducted from factor income and transfers added, giving disposable income, which by definition is related to place of residence.

Disposable income is the basis for determination of private consumption in market prices, by place of residence (cell TG). Private consumption is divided into tourism (domestic and international) and local private consumption (cell TV) and assigned to place of commodity market (cell SV) using a shopping model for local private consumption and a travel model for domestic tourism. Private consumption, together with intermediate consumption, public consumption and investments, constitutes the total local demand for commodities (cell SV) in basic prices through a use matrix, including information on the commodity composition of demand and commodity tax rates and trade margin shares. In this transformation from market prices to basic prices commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production (cell SV). Through a trade model exports to other regions and production for the region itself are determined. Adding export abroad, gross output by commodity is determined (cell RV). Through a reverse make matrix the cycle returns to production by sector (cell RE).

Figure 4. Real circle in LINE – the impacts of price and wage changes on economic activity and behaviour

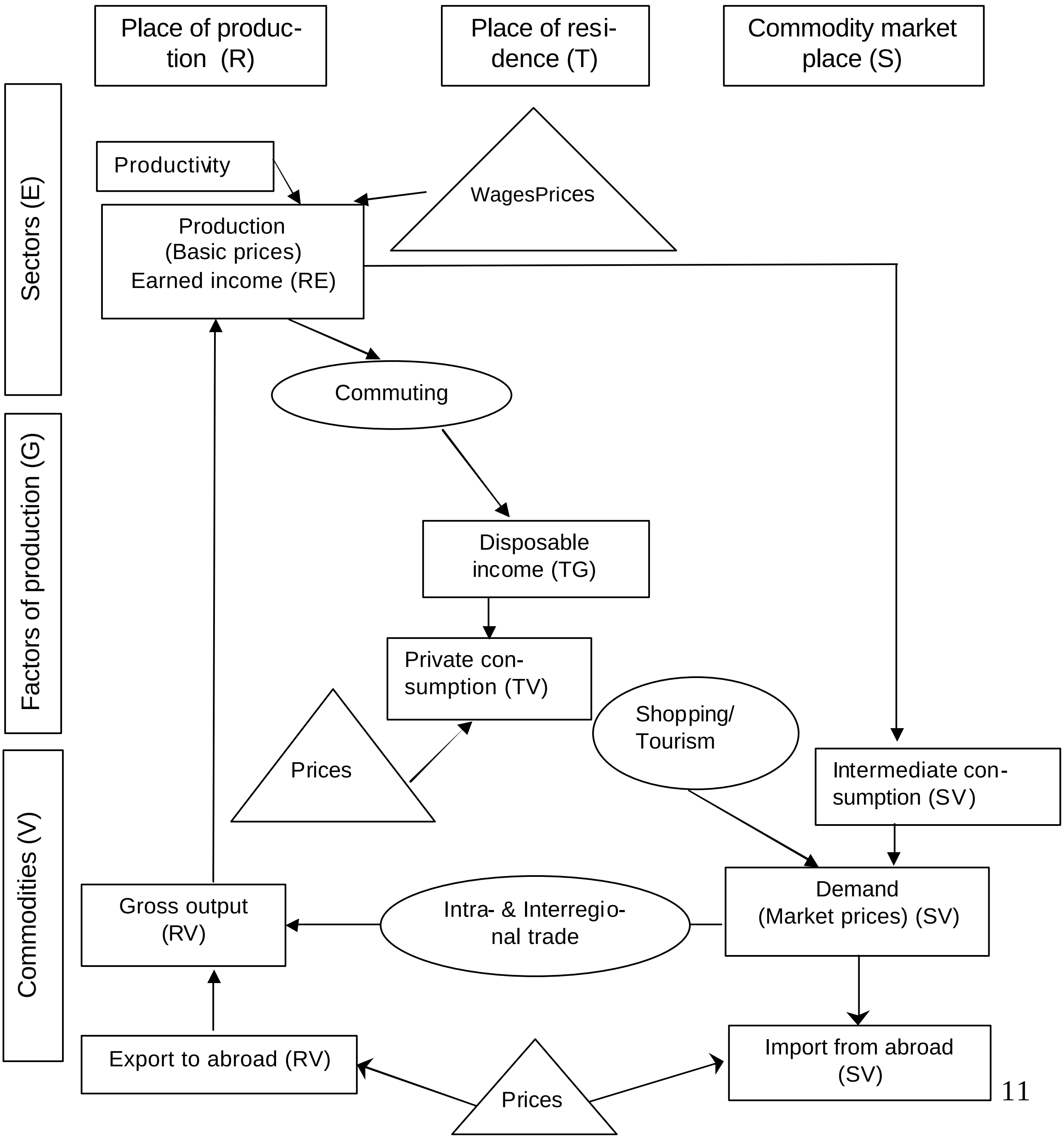
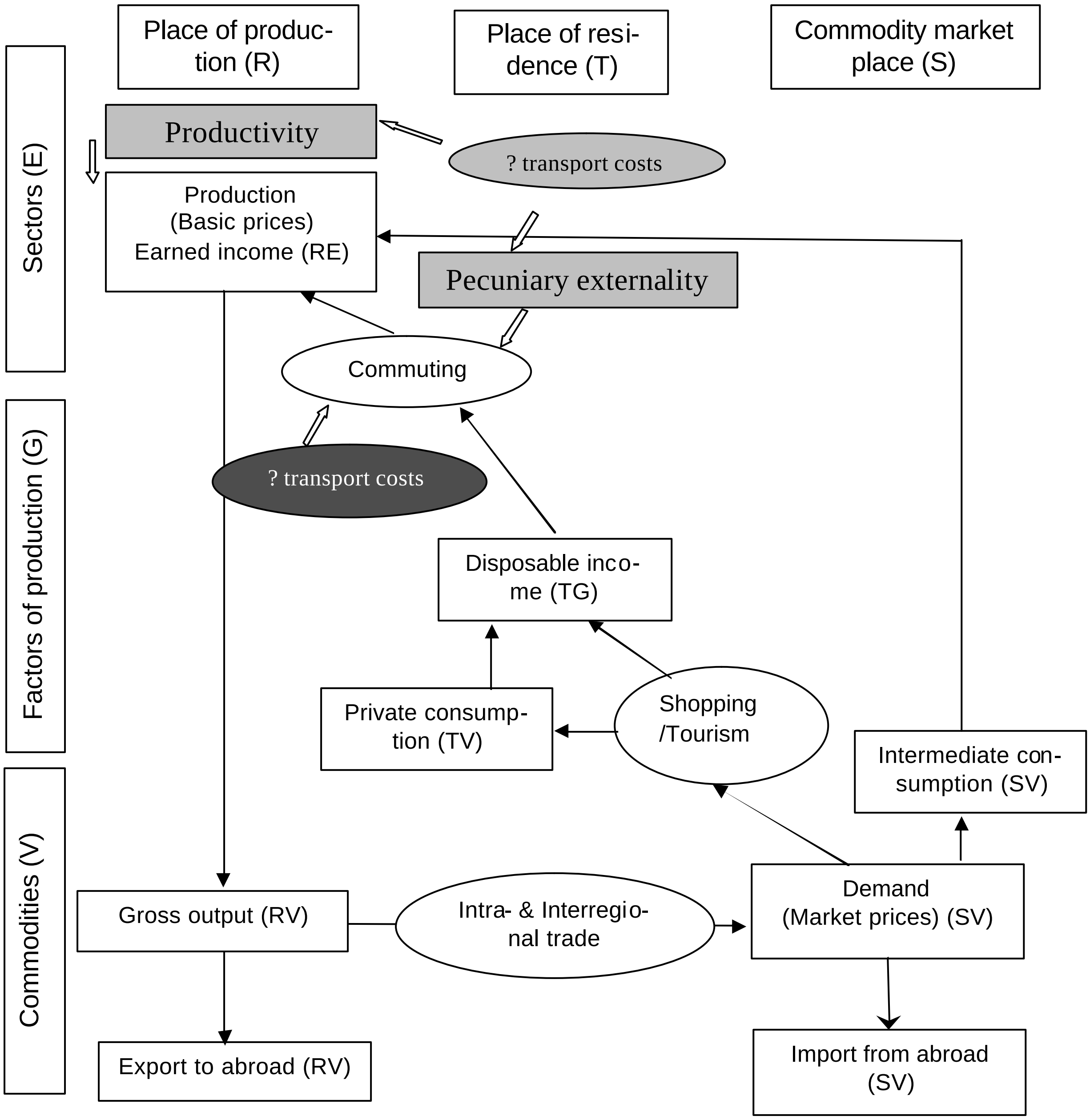


Figure 5. The cost-price circle in LINE. The impacts of transport cost changes on prices and wages



Economic activity in the real circle (figure 4) is affected by changes in prices and wages: wages and productivity affect prices of the local production, which through relative changes in local competitiveness affects exports and imports which in turn affects private consumption through changes in real disposable income. The anticlockwise cost/price circuit shown in figure 5 corresponds to this dual problem. In the cost-price circle, production and demand are calculated in current prices, which in turn are transformed into relevant price indices. In the upper left corner (cell RE) production in current prices (in basic prices) is determined by costs (intermediate consumption, value added and indirect taxes, net in relation to production) and productivity. Through a make matrix, sector prices by sector are transformed into sector prices by commodity (cell RV). These are then transformed from place of production to place of demand (cell SV) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes. This transformation takes place using a reverse use matrix. Commodities for intermediate consumption enter into the next step in the production chain (cell RE), determining prices of production and these prices are spread further in a round-by-round distribution process. Finally, private consumption is transformed from place of commodity market (cell SV) to place of residence in market prices (cell TV and TG).

4.2 LINE: Configuration
In this version of LINE the model configuration is the following:

Sectors:
21 sectors aggregated from the 133 sectors used in the national accounts.

Factors:
7 age, 2 gender and 5 education groups.

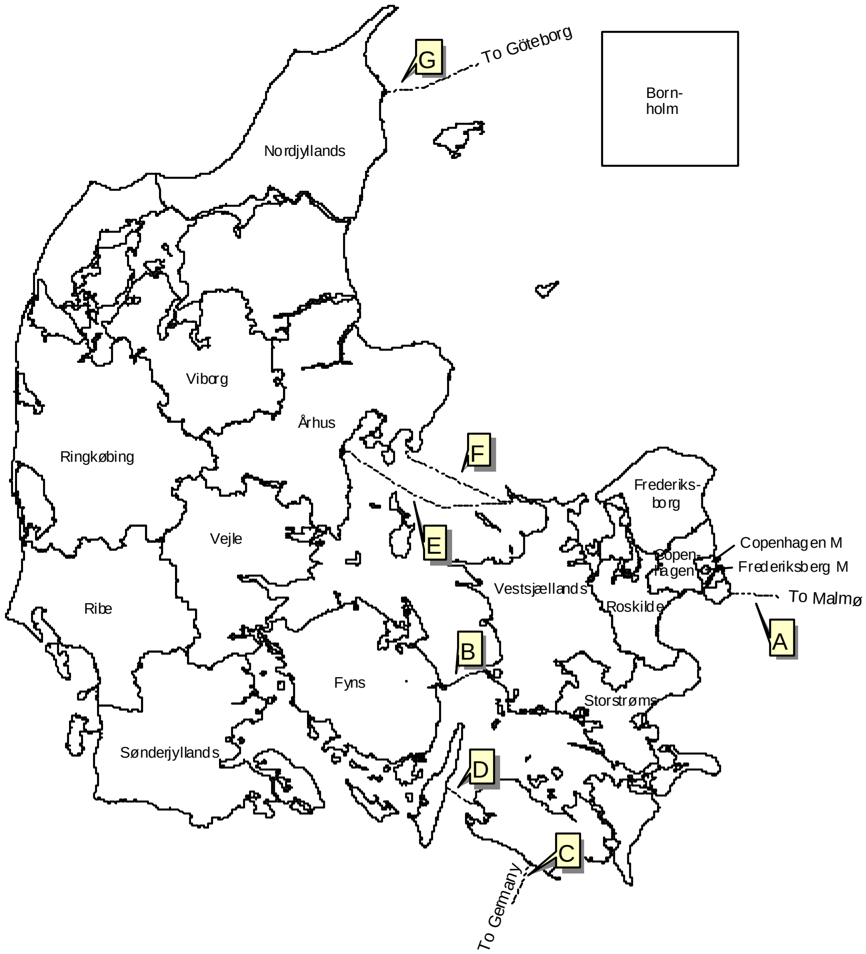
Households:
4 types, based upon household composition

Needs:
For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.

Commodities:
27 commodities, aggregated from 131 commodities used in the national accounts.

Regions:
277 municipalities, including one state-owned island and one unit for extra-regional activities, this being the lowest level of spatial disaggregation. Regions are defined either as place of production, place of residence or as place of commodity market. In this version of LINE the (277) municipalities have been aggregated into 16 regional units, including one unit for extra-regional activities.

Figure 6. Danish regions (counties and two municipalities with county status, Copenhagen M and Frederiksberg M). Three fixed links: A: Oresund, to Malmo, Sweden, B: Great Belt, C: Fehmern Belt to Germany. Four ferry routes: D : Spodsbjerg-Taars, E: Odden-Aarhus (Mols Line), F: Odden-Ebeltoft (Mols Line), G: Frederikshavn-Gothenburg (Sweden). Other very local and international ferry routes are not shown



4.3 Direct wage and price effects in LINE

As described above, wages and prices will change as teleworking is abandoned. There are three direct effects, one which is truly direct, one which arises through creation or reinforcement of externalities and one arising from productivity effects of teleworking. The two last effects have in turn an impact on prices. In figure 5 the three types of direct effect on wages and prices are shown. The true direct effect is shown by ellipses with dark shading, whilst the effects which operate through externalities and productivity are shown by ellipses with lighter shading. The first effect enters directly into the cost and price circle as an addition to costs and prices. In figure 5 an increase in commuting costs implies that disposable income is reduced directly. The second effect works through pecuniary externalities, which influence equilibrium wages and prices. In figure 5 a change in transport costs changes the size of the labour market and thereby the equilibrium wage. Changes in wages lead to changes in prices of production and in prices of commodities, following the logic of the cost-price circle. A change in productivity will also affect the level of wages and prices. This in turn changes the prices of commodities following the logic of the cost-price circle. Wages also change, but to a minor degree influence the disposable income.

It should be noted that this discussion and illustration of the effect of externalities and productivity is limited to the consequences of changes in transport costs for wages, as shown in figure 5. Similar effects could be illustrated in relation to the commodity market in the case of teleshopping.

The indirect and induced effects of wage and price changes depend in the medium term on exchange-rate regimes. If the economy is based upon fixed exchange rates, it matters whether or not a change in real wages leads to changes in nominal wages or changes in prices or a combination of these two. If wages change, assuming sticky prices, then competitiveness of domestic production is unchanged and the wage change will only have a minor impact on economic activity. On the other hand, if prices change, assuming sticky wages, then competitiveness of domestic production and international export and import will react with corresponding, more substantial effects on economic activity.

If the economy is based upon floating exchange rates, then changes in competitiveness due to changing prices will be more moderate as price changes will tend to be neutralised by exchange rate fluctuations. In this analysis fixed exchange rate regime is assumed.

5. Results

The main aim of this part of the analysis is to examine the effects of teleworking on regional economic activity. This includes its consequences for income net of commuting cost, for pecuniary externalities and for productivity. To examine these effects, the hypothetical case of abandonment of teleworking in Denmark is examined. In the presentation of the results, the sign has been reversed to show the positive impacts of teleworking. First, teleworking in Denmark is examined, followed by a description of the way in which transport costs are affected. Second, total effects on regional economic activity including the direct, indirect and induced effects and impacts on cost and prices (the results from the cost-price circle) and on production, income and employment (the results from the real circle) are presented. Finally, the total effects divided into direct transport cost effects (section 3.1), pecuniary externality effects (section 3.2) and productivity effects (section 3.3) are examined.

5.1 Teleworking and changes in transport costs

On the basis of an estimation of the share of teleworkers in employment by region and the intensity of teleworking, given that a person is a teleworker (section 3.1) the number of teleworkers and the share of teleworkers by region have been estimated.

Table 3. Number of full time teleworkers[1] and changes in car commuting cost abandoning teleworking by region (%)

	Number of full-time teleworkers	Full-time tele-workers' share of regional employ-ment	Reduction in commuting cost in million DKK	Reduction as share of earned income
Copenhagen & Fred.berg M	3735	0,99	-37	-0,036
Copenhagen C	3490	0,94	-34	-0,033
Frederiksborg C	1092	0,69	-10	-0,025
Roskilde C	626	0,64	-5	-0,023
Vestsjællands C	685	0,53	-6	-0,019
Storstrøms C	517	0,48	-4	-0,017
Bornholms C	84	0,42	-1	-0,015
Fyns C	1157	0,51	-9	-0,019
Sønderjyllands C	646	0,52	-5	-0,019
Ribe C	637	0,53	-5	-0,019
Vejle C	1042	0,56	-9	-0,020
Ringkøbing C	735	0,49	-6	-0,018
Århus C	2049	0,62	-17	-0,022
Viborg C	616	0,50	-5	-0,018
Nordjyllands C	1298	0,53	-11	-0,019
Total	18409	0,66	-164	-0,024

[1] The number of full-time teleworkers has been estimated using the results from the binomial logit model which has full-time telework as the dependent variable. The regression equation has been used to model the number of full-time teleworkers in each region using data from the local national accounts as independent variables.
M = Municipality, C = County.

The number of full-time (equivalent) teleworkers is estimated to about 18,000 or 0.66% of employment. The share of full-time teleworkers of employment is highest in the Greater Copenhagen area. This is because income and education levels are highest here and share of services in the economy is higher than the national average. As a consequence, the reduction in commuting costs through teleworking (columns 3 and 4) is highest in the Greater Copenhagen area.

Changes in commuting costs are based upon calculation of transport costs using an interregional satellite account for transport which is used to determine levels of transport costs together with exogenously given interregional transport costs, based on a digital road map, Vejnet DK, which is used to calculate the interregional transport costs.

The data in the interregional satellite accounts are estimated in four steps:

First, taking the national make and use tables, national transport activity is determined by i) transport mode ii) subdivided by transport costs related to intermediate consumption (by sector) and to private consumption (by component) and iii) external (transport firm based) and internal (own transport, within a non-transport producing firm or a household) costs. Six different modes of transport activity are used in the interregional satellite accounts, four for passenger transport and two for goods. Passenger transport is divided into car, rail, aeroplane and other, and freight transport is divided into lorry and rail.

Second, the national transport activity related to passenger transport is subdivided (using data from the National Travel Survey) by trip purpose: i) commuting ii) shopping, iii) tourism iv) business travel and v) recreation.

Third, national transport activity is then divided by origin and destination using data on intra- and interregional trade (freight and business trip transport activity) and interregional shopping, tourism and commuting (personal trip transport activity)

Fourth, regional transport activity is then corrected (using regionalised National Travel Survey data) to ensure that the data reflect regional transport activity by mode.

Changes in interregional transport activity for commuting are estimated using the digital road map Vejnet DK. Transport costs in Vejnet DK are based upon both time and distance where the generalised cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. In addition, costs are calculated both with and without teleworking, assuming that commuting costs using a car are reduced proportionally. The calculations are based on assumptions shown in Table 4.

Table 4. Maximum speeds, distance and time costs, road pricing tariffs (DKK) (DKK 7.50 = about 1 Euro = about 1US$)

	Car
Motorway	110 km/h
Non-urban highway	80 km/h
Urban roads	50 km/h or local restrictions taken from VejnetDK
Distance cost per kilometre	1.82 DKK
Time cost per hour	0.75 DKK

Estimation of the level of transport activity by region, mode, purpose and by type of consumption described above reflects the basic assumption that data on transport activity obtained from National (transport satellite) Accounts used in a top-down procedure, are superior to data on transport activity obtained from different statistical sources, used in a bottom-up approach.

5.2 The effects of teleworking in Denmark on prices and costs

In this section the results of changes in transport costs on costs and prices are presented. The analyses include the direct effects of changes in commuting costs on income net of transportation costs and the externality and productivity effects of teleworking. The analyses begin in the interaction components of the cost-price circle shown in figure 4 and the results are presented in table 5.

Table 5. Cost and price changes for production, demand, export, import and private consumption when teleworking is introduced at the same level as today in percentages

	(1) Supply: Gross Value Added (RE)	(2) Inter-mediate consump-tion (RE)	(3) Gross output (RE)	(4) Gross output (RV)	(5) Foreign export (RV)	(6) Demand: Domestic production (SV)	(7) Foreign import (SV)	(8) Demand (SV)	(9) Private consump-tion Place of market place (SV)	(10) Private consump-tion Place of residence (TG)
Copenh. & Fred.b. M	-0.072	-0.032	-0.058	-0.052	-0.032	-0.057	0.002	-0.043	-0.031	-0.031
Copenhagen C	-0.067	-0.041	-0.062	-0.062	-0.108	-0.056	0.002	-0.046	-0.031	-0.029
Frederiksborg C	-0.048	-0.031	-0.048	-0.045	-0.067	-0.043	0.001	-0.035	-0.022	-0.023
Roskilde C	-0.043	-0.030	-0.045	-0.041	-0.054	-0.041	0.001	-0.033	-0.021	-0.022
Vestsjællands C	-0.038	-0.025	-0.043	-0.037	-0.045	-0.037	0.002	-0.030	-0.021	-0.021
Storstrøms C	-0.033	-0.026	-0.037	-0.032	-0.033	-0.035	0.002	-0.029	-0.020	-0.019
Bornholms C	-0.029	-0.026	-0.034	-0.029	-0.030	-0.034	0.001	-0.030	-0.020	-0.019
Fyns C	-0.035	-0.024	-0.037	-0.032	-0.034	-0.034	0.001	-0.028	-0.019	-0.018
Sønderjyllands C	-0.036	-0.025	-0.039	-0.033	-0.033	-0.035	0.001	-0.029	-0.020	-0.022
Ribe C	-0.037	-0.025	-0.041	-0.035	-0.041	-0.036	0.001	-0.029	-0.020	-0.020
Vejle C	-0.038	-0.025	-0.042	-0.036	-0.043	-0.036	0.002	-0.029	-0.021	-0.019
Ringkøbing C	-0.033	-0.024	-0.042	-0.034	-0.044	-0.035	0.001	-0.027	-0.020	-0.020
Århus C	-0.043	-0.028	-0.043	-0.038	-0.042	-0.039	0.001	-0.031	-0.021	-0.020
Viborg C	-0.035	-0.024	-0.040	-0.033	-0.037	-0.035	0.001	-0.028	-0.020	-0.021
Nordjyllands C	-0.037	-0.025	-0.040	-0.034	-0.036	-0.035	0.001	-0.029	-0.020	-0.020
Outside regions	0.000	-0.015	-0.010	-0.001	-0.001	-0.025	0.002	-0.019	-	-
Total	-0.047	-0.029	-0.047	-0.042	-0.048	-0.042	0.001	-0.034	-0.023	-0.023

C: County, M: Municipality.

Starting with Gross Value Added (column 1), the GVA deflator (cost index) is reduced by 0.047% because of the reduction in transport costs for commuting. This occurs because wages are reduced through the pecuniary externality effect (see section 3.2) and because productivity increases, when teleworking occurs (see section 3.3). The decline in the value of the GVA deflator is essential because of the limited extent of teleworking in Denmark. Reduction in the GVA deflator causes prices on gross output to fall (column 3). This in turn leads to falling export prices (column 5) and prices of production for the domestic market (column 6). This in turn leads to falling prices for private consumption at the place of commodity market (column 9) and for private consumption at place of residence (column 10).

The regional pattern shows that the decrease in cost and prices is highest in Greater Copenhagen, where the share of teleworkers is highest. Greater Copenhagen will therefore experience the biggest productivity gains and reduction in wages due to teleworking. In Jutland, regions with lower levels of income and education have lower shares of teleworkers. This means that reduction in costs and prices is smaller.

5.3 Effects of teleworking on production, income and employment (the real circle)

The consequences for real economic activity arising from the changes in transport costs and the effects of these on costs and prices are presented. The analyses include externality and productivity effects as well as the demand effects arising from changes in disposable income due to reduced transport costs. Presentation of the effects arising from the real circle can be illustrated with reference to figure 4. The results are presented in table 6. The main impact of teleworking arises in foreign export, which increases as export prices decrease. This explains the net positive effect on production and employment, whilst the impact on disposable income is ambiguous.

Table 6. Consequences for demand, production and income when teleworking is introduced at the same level as today

	(1) Disposable income (current prices) (TG)	(2) Real disposable Income (TG)	(3) Private consumption Place of residence (TV)	(4) Private consumption Place of demand (SV)	(5) Demand (SV)	(6) Foreign imports (SV)	(7) Demand: Domestic production (SV)	(8) Foreign export (RV)	(9) Gross output (RE)	(10) GDP at factor prices (RG)
Copenh. & Fred.b. M	-0.030	-0.018	-0.018	-0.010	0.001	-0.006	0.003	0.029	0.009	0.003
Copenhagen C	-0.023	0.031	0.031	0.025	0.031	0.027	0.032	0.170	0.043	0.040
Frederiksborg C	-0.017	-0.008	-0.009	-0.007	0.011	0.003	0.013	0.116	0.027	0.022
Roskilde C	-0.019	0.006	0.005	0.006	0.013	0.006	0.015	0.102	0.025	0.018
Vestsjællands C	-0.013	0.003	0.003	0.003	0.014	0.007	0.016	0.092	0.029	0.017
Storstrøms C	-0.009	0.025	0.025	0.023	0.016	0.008	0.018	0.062	0.024	0.018
Bornholms C	-0.008	0.015	0.015	0.015	0.013	0.004	0.015	0.053	0.021	0.014
Fyns C	-0.010	0.014	0.014	0.013	0.014	0.007	0.016	0.061	0.024	0.016
Sønderjyllands C	-0.011	-0.026	-0.026	-0.024	0.006	0.002	0.010	0.055	0.021	0.010
Ribe C	-0.010	0.009	0.010	0.009	0.018	0.012	0.020	0.076	0.031	0.022
Vejle C	-0.009	0.032	0.032	0.030	0.024	0.016	0.026	0.076	0.035	0.026
Ringkøbing C	-0.011	0.006	0.006	0.006	0.021	0.014	0.023	0.078	0.035	0.022
Århus C	-0.013	0.009	0.008	0.008	0.014	0.007	0.016	0.073	0.025	0.016
Viborg C	-0.010	0.000	0.000	0.000	0.015	0.009	0.016	0.067	0.028	0.017
Nordjyllands C	-0.011	0.004	0.004	0.005	0.013	0.007	0.015	0.062	0.024	0.014
Outside regions	-	-	-	-	0.003	-0.003	0.005	0.000	0.018	0.014
Total	-0.015	0.007	0.007	0.007	0.015	0.008	0.016	0.075	0.026	0.019

C: County, M: Municipality.

Starting with private consumption (column 3), prices decline as a result of falling wages and increased productivity. This is combined with changes in disposable income in current prices (column 1), where the reduction in commuting costs and the increase in economic activity causes the disposable income to grow, whilst the reduction in wages, increases in taxation and declines in income transfers all contribute negatively to disposable income. The net effect is an increase in real disposable income at national level, with a mixed pattern of regional gains and losses. Copenhagen County benefits most, whilst a number of rural counties in western Denmark and together with Copenhagen and Frederiksberg Municipalities lose.

A principal explanation of this result is the reduction in foreign export prices. As foreign export from Copenhagen and Frederiksberg Municipalities is insensitive to changes in export prices, there is little change in volume of exports (column 8). A further consequence is that changes in gross output in the two municipalities are very limited. This can be compared with the positive impacts of changes in prices on export volumes from Copenhagen County, combined with the fact that elasticities for the commodities exported from this region are much larger. Thus, real disposable income increases in Copenhagen County and declines in Copenhagen and Frederiksberg Municipalities.

Table 7. Consequences for employment and income when telework is introduced

	(1)		(2)		(3)	(4)	(5)	(6)
	Employment at place of production (RG)		Employment at place of residence (TG)		Primary income (TG)	Income transfers (TG)	Taxes (TG)	Disposable income (TG)
	– pct –	Number	– pct –	Number	Per cent			
Copenhagen & Frederiksberg M	-0.005	-17	0.002	6	-0.046	-0.010	-0.049	-0.030
Copenhagen C	0.019	71	0.012	37	-0.028	-0.024	-0.032	-0.023
Frederiksborg C	0.010	15	0.010	19	-0.018	-0.025	-0.023	-0.017
Roskilde C	0.011	11	0.010	14	-0.020	-0.029	-0.028	-0.019
Vestsjællands C	0.008	10	0.008	13	-0.016	-0.014	-0.021	-0.013
Storstrøms C	0.011	12	0.011	13	-0.011	-0.012	-0.016	-0.009
Bornholms C	0.008	2	0.008	2	-0.010	-0.008	-0.014	-0.008
Fyns C	0.009	20	0.009	21	-0.011	-0.013	-0.016	-0.010
Sønderjyll. C	0.004	5	0.004	6	-0.012	-0.014	-0.017	-0.011
Ribe C	0.011	13	0.011	13	-0.009	-0.023	-0.015	-0.010
Vejle C	0.015	28	0.014	26	-0.006	-0.024	-0.012	-0.009
Ringkøbing C	0.012	18	0.012	17	-0.006	-0.036	-0.015	-0.011
Århus C	0.009	31	0.009	31	-0.015	-0.018	-0.020	-0.013
Viborg C	0.009	11	0.009	11	-0.008	-0.023	-0.015	-0.010
Nordjyllands C	0.008	19	0.008	19	-0.012	-0.014	-0.017	-0.011
Total	0.009	246	0.009	246	-0.018	-0.018	-0.024	-0.015

5.4 Decomposition analysis of the impacts of teleworking

As argued above the consequences of teleworking for a regional economy can be divided into 3 components: 1) The demand effects created by increases in income net of commuting arising from reductions in transport costs through the introduction of teleworking; 2) the wage reduction effect associated with enlargement of the labour market arising from reductions in commuting costs; and 3) the effects on prices of higher productivity after the introduction of teleworking as an alternative production technology. In table 8 the employment effects created by each component are presented:

Table 8. Impacts on employment at place production when telework is introduced: A decomposition analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Commuting cost decline	Labour market negotiation	Productivity increases	Total =1+2+3	Commuting cost decline	Labour market negotiation	Productivity increases	Total =5+6+7
	Number				Per cent			
Copenhagen & Frederiksberg M	-26	7	12	-7	-0.006	0.002	0.003	-0.002
Copenhagen C	15	49	40	104	0.004	0.014	0.011	0.029
Frederiksborg C	9	5	10	23	0.006	0.003	0.007	0.016
Roskilde C	5	5	3	13	0.006	0.005	0.004	0.015
Vestsjællands C	4	5	6	16	0.004	0.004	0.005	0.013
Storstrøms C	4	8	3	15	0.004	0.008	0.003	0.015
Bornholms C	0	1	1	2	0.003	0.006	0.004	0.013
Fyns C	7	14	10	31	0.003	0.006	0.005	0.014
Sønderjyllands C	4	1	9	13	0.003	0.001	0.007	0.011
Ribe C	4	9	9	22	0.003	0.008	0.008	0.019
Vejle C	7	21	13	40	0.004	0.011	0.007	0.022
Ringkøbing C	4	14	13	32	0.003	0.010	0.009	0.021
Århus C	13	18	16	47	0.004	0.006	0.005	0.015
Viborg C	4	7	9	20	0.003	0.006	0.007	0.016
Nordjyllands C	8	12	12	32	0.003	0.005	0.005	0.014
Outside regions	0	0	0	0	0.001	0.002	0.003	0.005
Total	60	177	165	402	0.002	0.007	0.006	0.015

First, for Denmark reduction in transport costs associated with teleworking and affecting disposable income has an employment effect of 60 persons or 0.002% of national employment (see column 1). The employment effects are caused by the increase in disposable income, which increases private consumption, which in turn has effect on production and employment. The impacts are biggest in regions with a high share of teleworkers, except in the case of Copenhagen and Frederiksberg Municipalities. Here curiously, the effects are negative because of neutralising effects on disposable income from the system of unemployment benefits.

Second, reductions in commuting costs enlarge labour markets generating a reduction in wages. This in turn reduces prices of production, foreign exports and commodities, which enter into private consumption. A whole series of indirect and induced effects are generated, which creates a total employment effect on 177 (see column 2). The regional distribution of these effects is determined by the distribution of the relative share of teleworkers and the decline in commuting costs. The impact on Copenhagen and Frederiksberg Municipalities is very limited reflecting low price elasticity in this area, which can mainly be explained by the commodity composition of the foreign exports.

Finally, the impact of productivity gains is 165 (column 3) and the regional distribution follows that of the labour market effect.

6. Conclusions

There is a general view, that the frequency and extent of teleworking will grow markedly in the future. This will be driven by rising income, outsourcing, rising levels of qualification and increased technological opportunities. There will also be positive external effects as congestion is reduced and emissions to the environment related to transport activities decline.

The regional economic impacts of teleworking have been examined using Denmark as a case. The study shows that at present in terms of income and employment creation the effects of teleworking are very limited. This is primarily because the number of full-time equivalent teleworkers in Denmark is very small, amounting to only 0.6% employment.

An interregional general equilibrium model for Denmark, LINE, has been used to evaluate the 3 major economic effects arising from teleworking. First, there is the demand effect arising from increases in disposable income associated with reductions in transport costs. Second, wages and therefore commodity prices decline, as teleworking enlarges labour markets, making labour more accessible. This constitutes a pecuniary externality. Third, costs and prices are reduced as teleworking increases labour productivity compared with working exclusively at the place of work. LINE provides estimates of these effects at national and regional levels.

The share of teleworkers in the Greater Copenhagen area is substantially higher than in the rest of Denmark. This is primarily explained by higher income and educational level as well as sectoral composition and high commuting costs. This means that the benefit from reduction in commuting costs, the labour market enlargement, and the productivity gains arising from teleworking are greater here.

Finally, the study is a methodological contribution to efforts to integrate into an overall and consistent modelling framework the analysis of an exogenous technological change, which has a number of seemingly different impacts. This framework has been provided by the interregional general equilibrium model for Denmark (LINE) in combination with partial direct effects of the introduction of teleworking these being based upon independent econometric studies.

Appendix 1

Table A1.1. Binomial logit model with teleworking as the dependent variable

Variable	Coefficient	t-statistic
Constant	-9.312	-19.35
Female	0.032	0.30
Age group (ref. under 30)		
31-40	0.177	0.95
41-50	0.169	0.88
Over 50	-0.109	-0.56
Work in public sector (ref. work in private sector)	0.172	1.84
Couple	0.148	1.02
Children aged 0 – 4 in household	-0.090	-0.68
Children aged 5 – 9 in household	0.409	3.58
Children aged 10 – 15 in household	-0.116	-1.00
Educational level (ref. compulsory education)		
High school	1.737	4.80
Trade qualifications	0.961	2.84
Higher education: short	1.676	4.52
Higher education: medium	1.925	5.73
Higher education: long	2.343	6.92
Gross income per year (in thousands of DKK)	0.010	10.88
Gross income per year squared	-0.000006	-8.41
Household car ownership divided by number of workers	0.361	2.61
Average length of working week (hours)	0.044	7.41
Distance from home to workplace (kilometres)	0.004	3.04
Sample size	10435	
Log-likelihood (constant only)	-2301.595	
Log-likelihood (at convergence)	-1851.673	
Rho-squared	0.195	

Appendix 2

Table A2.1. Wage differentials and commuting distances. Estimated parameters and standard errors

Dependent variable: ln(average yearly wage)	FGLS	WLS	OLS
Intercept	12.00 (0.0020)	11.96 (0.0012)	11.95 (0.0031)
Gender	0.21 (0.00058)	0.20 (0.00032)	0.19 (0.00090)
Year=1999	0.05 (0.00089)	0.06 (0.00051)	0.05 (0.0014)
Year=1998	0.03 (0.00086)	0.05 (0.00048)	0.03 (0.0013)
Year=1997	0.01 (0.00081)	0.02 (0.00046)	0.01 (0.0013)
Long further and higher education	0.46 (0.0011)	0.50 (0.00071)	0.46 (0.0016)
Middle-range further and higher education	0.29 (0.00090)	0.29 (0.00055)	0.30 (0.0014)
Short further and higher education	0.18 (0.0010)	0.17 (0.00068)	0.19 (0.0015)
Skilled worker	0.10 (0.00070)	0.10 (0.00037)	0.10 (0.0011)
Age 45-59	0.30 (0.00074)	0.28 (0.00043)	0.31 (0.0011)
Age 30-44	0.24 (0.00071)	0.23 (0.00041)	0.24 (0.0011)
ln(unemployment)	-0.07 (0.00083)	-0.04 (0.00047)	-0.07 (0.0013)
ln(commuting distance)	0.03 (0.00023)	0.03 (0.00016)	0.04 (0.00037)
* Adjusted R^2	-	-	0.2626

Note: All variables are significant at a 10% level. If all dummy variables are zero the representation is: Gender=female, year=1996, basic education, and age 15-29 years old.

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Section 15:

Regional Economic Impacts of Traffic Regulation on Tourism: The Case of Denmark

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REGIONAL ECONOMIC IMPACTS OF TRAFFIC REGULATION ON TOURISM: THE CASE OF DENMARK

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The paper presents an interregional computable general equilibrium model, LINE, which is used to analyze the regional economic effects of changes in road pricing as they affect and work though the Danish tourism sector. These effects include changes in demand, income and employment by region. The form of road pricing examined in the paper is tolls across a major fixed link. The consequences of changes in these substantial tolls are examined using the modeling framework. The basic modeling approach in LINE is presented, including its tourism sub-model, and empirical results for Denmark are examined.

1. Introduction

The economic importance of tourism is growing. At the same time, taxation of transport is rapidly becoming an important political issue, largely because of its potential for reducing congestion and environmental externalities. Tourism also makes an important contribution to increasing traffic volumes, in turn creating both environmental and congestion problems. Growth in these problems has led to demands for regulation of the transport system and of traffic, which in turn have consequences for tourism. The main theme of the paper is the modeling of tourism as a regional economic phenomenon, with particular reference to the effects of changes in the price of the tourism product which arise because of changes in road pricing.

The regulation of traffic through charging levies on users of roads has a number of impacts on tourism. The first and most obvious impact is that as transport becomes more expensive, the price of the tourism product will increase. As tourism, compared with other types of demand, has an important transport component, in relative terms, price increases will be substantial and demand will decline. The magnitude of the change in demand is determined by price elasticity of demand in tourism (Jensen 1998). Second, the prices of other commodities consumed by tourists will also increase, as the price of commodity transport increases. Third, taxes on transport will, in general, influence choices made by households between leisure and work time, affecting both consumption of tourism and the labor market. Transport is a component of leisure consumption and as transport (and leisure) becomes relatively more expensive, households will substitute away from leisure towards work. This, of course, rests on a number of assumptions, including that leisure is a normal good. There is a substantial literature and debate on this double dividend effect. (See for example Goulder 1995, Parry & Bento, 2001.) There can also be offsetting effects arising from the positive effects of taxation on transport, including lower levels of congestion, leading to time savings, environmental improvement and modal shifts.

A central method of taxation of transport, which is at present emerging, is road pricing, covering both cars and lorries. The road pricing issue is also gaining importance because the technical possibilities upon which road pricing systems are based have expanded rapidly, reducing dramatically the implementation, operational and administrative costs of such systems. Road pricing until now has typically involved payment of a toll for passing a cordon, or a fixed tariff for entering an area, in both cases typically an urban center. More sophisticated road pricing schemes involve GPS based continuous on-vehicle monitoring of distances driven, by type of road and time of day. This road pricing system is continuous, on-vehicle and operates with different levels of taxation, according to area, type of road, time of day and type of vehicle.

The effects of road pricing differ depending upon whether it is implemented unilaterally in a country, and whether it covers different means of transport. Unilateral implementation means that the price paid by domestic tourists for the tourism product reflects their use of domestic roads. For foreign tourists, the increase in the price of the tourism product simply reflects the cost of the fixed entry tariff. These price increases have effects on the number of tourists. Changes in income from tourism have a range of indirect and induced effects on income and employment as well as on regional labor markets, as employment declines.

The approach employed in this paper to analysis of the consequences for tourism of road pricing, is regional and employs an interregional computable general equilibrium model. The first step calculates price increases which arise from increases in commodity prices as commodities are transported from place of production to place of demand. The second step is to calculate increases in prices for the tourism product. The third step involves calculation of changes in demand for tourism (number of tourists) as a consequence of the price increases. In principle, the effects on different groups of tourists could be examined. The model permits analysis by tourists' nationality or social group. However, the distributional effects of changes in taxation are not the central focus of this paper. In the fourth step the direct, indirect and induced effects on income and employment are calculated, again by region. In several following steps, the effects of alternative uses of the revenue arising from road pricing, for example reduction in income tax or increased governmental consumption, are calculated. The positive effects of changes in transport taxation are not included in the present analysis, though the modeling approach does not, in principle, prohibit this. Rather, it is a problem of the correct specification of transport costs

In this study a rather specific case of changes in road prices has been chosen, using Denmark as an example. As described in more detail later in the paper, the effects on tourism of eliminating tolls for crossing the principal Danish fixed link, the Great Belt link, are evaluated. While this problem may appear to be minor, it is in fact not the case, as the Great Belt link tolls are substantial and Denmark is a small country. Removing the tolls corresponds to a unilateral change in road pricing. The theoretical approach developed is quite general, and can be applied to any change in transport costs, for example changes caused by environmental regulation, by rising fuel prices or by transport infrastructure improvements.

The following section briefly examines different systems of road pricing, and the incorporation of road pricing into a general equilibrium modeling approach. In Section 3 the model, LINE is presented graphically. In Section 4 the way in which the tourist sector enters into both the regional economy and the model is examined, including the relationships between transport and tourism. Section 5 presents initial results based upon specific assumptions concerning the application of road pricing in Denmark in the form of tariff changes on the Great Belt link. Conclusions are drawn in Section 6.

2. Road pricing and modeling its impacts on tourism

There is an extensive literature on road pricing and its economic consequences. (See for example Johansson & Mattsson, 1995, De Borger & Proost, 2001). The design of road pricing systems is not directly related to traffic flows generated by tourism, but rather arises from general issues concerning transport policy and technical constraints and possibilities, in concrete social and cultural contexts. Below, the general principles used to design road pricing systems are presented and the consequences of this design for tourism-generated traffic are examined.

2.1 Road pricing

Five basic dimensions underlie road pricing systems:

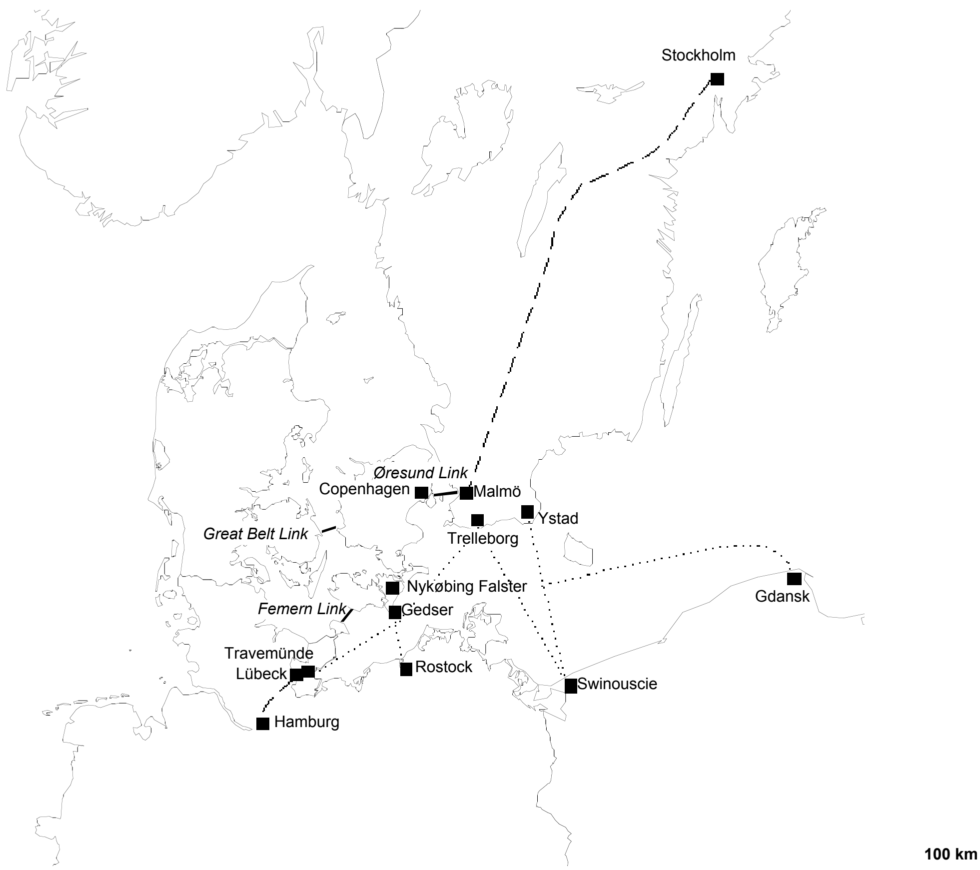
(1) Whether different transport modes are included;
(2) Whether the tariff depends on the type of road to be used (motorway, main road, secondary road etc);
(3) Whether the tariff depends upon type of area in which the road is used (for example, urban, rural or national territory);
(4) Time of day (rush hour, daytime, evening, night); and
(5) Whether the tariff is kilometer dependent, time-dependent or flat-rate.

For example, an urban cordon is a flat-rate charge for entering a specific type of area. A motorway toll is typically kilometer- and road-type dependent. Choice of system depends partly upon the dimensions chosen and partly upon technological, administrative and political alternatives available.

In Denmark a pilot project is being developed involving kilometer- and area-dependent tariffs. In the future, more complex systems that take account of the road hierarchy and time of day may be developed. Technically, it is based on GPS technology, permitting precise identification of location of the vehicle and thereby, road use, related in turn to toll level for the road. The toll level depends on road status in a road hierarchy and level of urbanization. Cars are to be fitted with receivers, which function as meters, registering both current expenditure as the road is used and cumulated expenditure for a given period. The meter is read at periodic intervals and the user is charged. (See Herslund et al. 2001, Nielsen 2000.)

In Denmark other important road pricing issues are the subject of both analysis and debate. There are at present two major fixed links across straits, the Øresund link and the Great Belt link, each around 15-20 kilometers in length (Figure 1). Passage of these links involves substantial tolls for vehicles, of the order of $US25-35 for a single trip in a car and substantially more for a lorry. At present this pricing policy is subject to major revision, including the possibility of removing tolls altogether on the Great Belt link. This form of road pricing can be regarded as a road-dependent toll, based upon a toll barrier. Pricing policy is also important in relation to the two other fixed links: a) between Sweden and Denmark, over the Øresund and the as yet only proposed fixed link between Denmark and Germany, over the Femer Belt. Pricing policy on these fixed links has direct consequences for German and Swedish tourism. There are a number of analyses of the regional economic effects of opening of fixed links (for example Jensen-Butler & Madsen 1996, 1999, Vickerman & Flowerdew, 1990, Bruinsma & Rietveld 1998) and choice of toll levels (Madsen et al 2002).

Figure 1. Øresund link and Great Belt link



The present paper examines the regional economic consequences of changes in tourism-related activity in relation to a new pricing policy on the Great Belt link. In particular, the effects of a proposal to reduce the substantial tolls on this fixed link to zero are analyzed. As such, a specific form of change in road pricing is being examined, rather than study of the regional economic effects of opening a new fixed link. The analysis will be extended in the near future to cover the effects of more general road pricing systems on the tourism sector and the regional economic consequences arising from these.

2.2 Traditional approaches to analysis of the economic effects of road pricing

A traditional approach involves identification of changes in transport flows and changes in direct and indirect (time) costs for travelers. This information is then used to undertake a cost-benefit analysis of the changes in the regulation of the transport system, involving an evaluation of changes in direct costs, time savings and changes in other costs, such as accidents and environmental costs. For tourists, changes in traffic flows, involving both time and distance and the valuation of time costs and kilometer dependent costs can be made. It is usually assumed that the value of a unit of time on a recreational trip is considerably lower than on a business trip.

Normally, the spread of changes in the costs of the transport sector to commodity prices and incomes in other sectors is not dealt with. In the case of tourism, the change in cost of tourism is not related to place of residence of the tourist. This means that the traditional cost-benefit approach cannot be used for analysis of distributional questions in relation to regions, factors, sectors and household types. In addition, as behavioral reactions from producers and consumers, including tourists, are not included explicitly in the cost-benefit approach, determination of the value of time for different categories of tourist is made exogenously, rather than endogenously.

2.3 A general equilibrium modeling approach to analysis of the economic effects of transport system changes on tourism

In the present analysis, the approach involves identification of the actors who experience the price change for transport and in the case of commodities, the way in which the price change is incorporated into changes in commodity prices at place of demand and finally their impact on economic activity.

The theoretical approach models the effects of road pricing on regional economies in two stages. In the first step a local economic model is used to estimate changes in commodity prices and incomes. This model is based upon linear input-output relations and does not involve behavioral reactions to changes in relative prices and income. In the second step, changes in behavioral relations are incorporated into the model, transforming it into a computable interregional general equilibrium model, permitting a fuller analysis of changes in prices on economic behavior in a regional system.

Changes in the transport system have consequences for costs and prices in the regional economy (step 1). In the local economic model cost and price changes are followed from place of production through the trade system to place of demand and further, to place of residence of the consumers and to place of production as intermediate inputs. This forms in the first round of (in principle) an infinite number of circles, which describe the propagation of cost and price changes in the (inter) regional economy. These cost and price changes constitute the basis of an analysis of the distributional effects of changes in the transport system, carried out in step 1 of the modeling process. In the case of the price of the tourism product, this involves transferring the taxes from the place of their application to the place of residence of the tourist. Initially, it is assumed that the tourist chooses the tourism product on the basis of price, including taxes for using roads.

Changes in prices in turn have consequences for tourists' behavior (step 2). Price increases reduce the number of foreign tourists in Denmark and Danish tourists will increasingly choose to go abroad. This in turn has an impact on regional/domestic demand, which in turn reduces production, income and employment. Results from step 2 have in turn consequences for determination of costs and prices (step 1). This is the iterative process that constitutes the framework for a general equilibrium approach.

3. An interregional local economic model (LINE)

A general equilibrium model, LINE, is applied to the tourism sector in Denmark. The model is described in detail in Madsen et al (2001a). The following two sections provide an outline of the model and its background. In Section 3.3 its specific tourism components are described and in Section 4 the concrete model specification is outlined.

3.1 Background

LINE is a local economic model, which has been developed at the Institute of Local Government Studies (AKF) in Copenhagen (Madsen et al 2001a). In this section a graphical overview of the LINE model is presented. First, the full model is presented, followed by the more limited model where the tourism component of LINE is examined.

The basic philosophy in the construction of LINE is, on the one hand, to describe in detail the structure of the local economy and on the other hand to include the fundamental interaction between real economic activities and the costs and prices related to these activities.

This interaction between real activity and costs and prices involves two types of interdependency. The real economy affects costs and prices, both in terms of level and changes and costs and prices affect the real economy, again both in terms of level and changes.

In relation to the first type of interdependency, local demand and supply in current prices in LINE are calculated by multiplying quantities by relevant unit costs and prices and then by summing costs and revenues to obtain totals which constitute the basis of a number of price indexes for local economic activities. These local cost and price indexes form the basis for decisions made by local producers and consumers, involving the determination of different types of real demand, such as intermediate consumption for local production (business tourism) and private consumption for local households (tourists).

In relation to the second type of interdependency, real demand in LINE creates production, which creates income, which in turn generates demand and so on. These demand and production structures form the basis for the calculation of local costs and prices. Thus, LINE develops both a cost-price circuit, corresponding to an input-output price model, described in Figure 2, and a circuit of real transactions, corresponding to the traditional Leontief real input-output model, described in Figure 3. The underlying model structure to be found in the figures is discussed in more detail below.

To illustrate the overall structure of LINE, a brief discussion of the characteristics of interregional local economic models is presented. These models are composite, as on the one hand they contain the two basic exchange circuits, the cost/price and the real circuits, which can, in principle, be modeled using linear relationships. On the other hand, these models usually contain a set of non-linear relations, which reflect *a priori*, in a consistent and mathematically manageable manner, producers' and consumers' behavior in a set of sub-models. These non-linear relationships involve consumption and production functions, including such elements as product variety and production externalities.

The modeling strategy chosen in the context of LINE is to begin with a simple model. The reason for this is that local economies involve different types of economic activity and actors (in SAM terminology, activities, factors, institutions, components of demand, commodities) and types of interaction (trade, commuting, shopping, tourism). If the main ambition is to produce a realistic picture of all these interdependencies, then a local economic model is much more complex compared with both national and regional models. Therefore, the strategy was to begin with a pure linear model having only few links from local prices to local economic behavior. However, a main conclusion of this modeling exercise is that even though the model is simple, a number of the most important issues for local economies related to road pricing and its impacts have been analyzed in a relevant and satisfactory manner.

A number of links between local prices and local demand, using non-linear forms, are included. Thus, in order to examine the effects of road pricing, the strategy is to go gradually and stepwise from a simple to a complex interregional general equilibrium analysis in order to trace effects of including links between costs and prices and economic activity. Even though it is tempting to include early on a number of non-linear relationships between costs and prices and real demand and production in the model, a high level of ambition can create confusion about the effect of each of the elements, leaving the model builder and user unclear about the marginal effects of each step. By following this more conservative strategy it will be easier to identify the specific contribution of each element.

3.2 LINE: an overview of the details

Figure 2 shows a stylized version of the cost and price circuit in LINE. The circle follows the formation of prices by an adding up process of cost in the production process and further to the market where transport costs and commodity taxes are included and further to place of residence including transport costs related to tourism and shopping. The horizontal dimension is spatial: place of work, place of residence and place of demand. Production activity, such as for example hotel activity, is related to place of work. Factor rewards (wages and profits) and income to institutions are related to place of residence, and demand for commodities, like tourist expenditure, is assigned to place of demand. The vertical dimension follows with its five-fold division the general structure of a SAM model (Madsen et al. 2001b). Production is related to activities; factor incomes are related to activities by sector, factors of production by qualification, gender and age and institutions (households and firms). Demand for commodities is related to wants (aggregates of commodities or components of final demand and intermediate consumption) and commodities, irrespective of use.

In cell AE (Figure 2) sector basic prices (measured in current prices) are determined by costs (intermediate consumption, value added and indirect taxes) excluding transport costs. Moving counter-clockwise through a reverse make matrix, sector prices by sector are transformed into sector prices by commodity, again in current prices (from AE to AV). In the trade model lying between AV and DV, changes in transport costs related to trade are added transforming the value of commodities into basic prices including transport costs. These are then transformed into market prices through inclusion of retailing and wholesaling costs and indirect taxes (from DV to DW). This transformation takes place using a reverse use matrix. Prices for intermediate consumption enter as production cost in the production (from DW to AE) closing the cost-price circle. Finally, private consumption is transformed from place of demand to place of residence in market prices including changes in transport costs (from DW to BW). Through all of these steps, current prices are used.

Figure 3 shows a stylized version of the real circle in LINE. The real circuit corresponds to a straightforward Keynesian model and moves clockwise. Starting in cell AE in the upper left corner, production generates factor income in basic prices including the part of income used to pay commuting costs. This factor income is redistributed from activities to factors (cell AE to cell AG), where the labor force is divided into qualification, gender and age groups. Factor income is then transformed from place of production (AG) to place of residence (BG) through a commuting model. In this process transport costs are subtracted from factor income. Disposable income is calculated in a sub-model where taxes are deducted and transfer and other incomes are added. Both direct and indirect taxes enter into the model. Disposable income is distributed from factors (BG) to households and firms (BH). This is the basis for determination of private consumption in market prices by place of residence (BW). Private consumption is assigned to place of demand (DW) using a tourism/shopping model. In this process, changes in transport costs related to tourism/shopping are subtracted. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities (DV) in basic prices through a use matrix. In this transformation from market prices to basic prices (from DW to DV) commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production. Through a trade model exports to other regions and production for the region itself are determined (from DV to AV). Adding export abroad, gross output by commodity is determined. Through a make matrix the cycle returns to production by sector (from AV to AE).

The two circles also constitute the solution routine for LINE, which technically is a Gauss-Seidel solution routine: In the first iteration values are calculated in both the real circle and the cost-price circle. First, the variable values in the real circle are calculated on the basis of preliminary values for gross output and GDP at factor prices, both by sector (AE in Figure 3) which follow the first round of iteration in this circle. Second, the variable values in the cost-price circle are calculated on the basis of preliminary values for commodity prices for intermediate consumption (entered in the cost-price circle in cell AE in Figure 2). Returning anti-clockwise to cell AE completes the first iteration. At the end of this iteration, the (preliminary) current values are replaced by the calculated price index for intermediate consumption by commodity. The process of calculation of values in the two circles continues until a convergent solution has been obtained.

Figure 2. Implified version of LINE: the cost-price circle

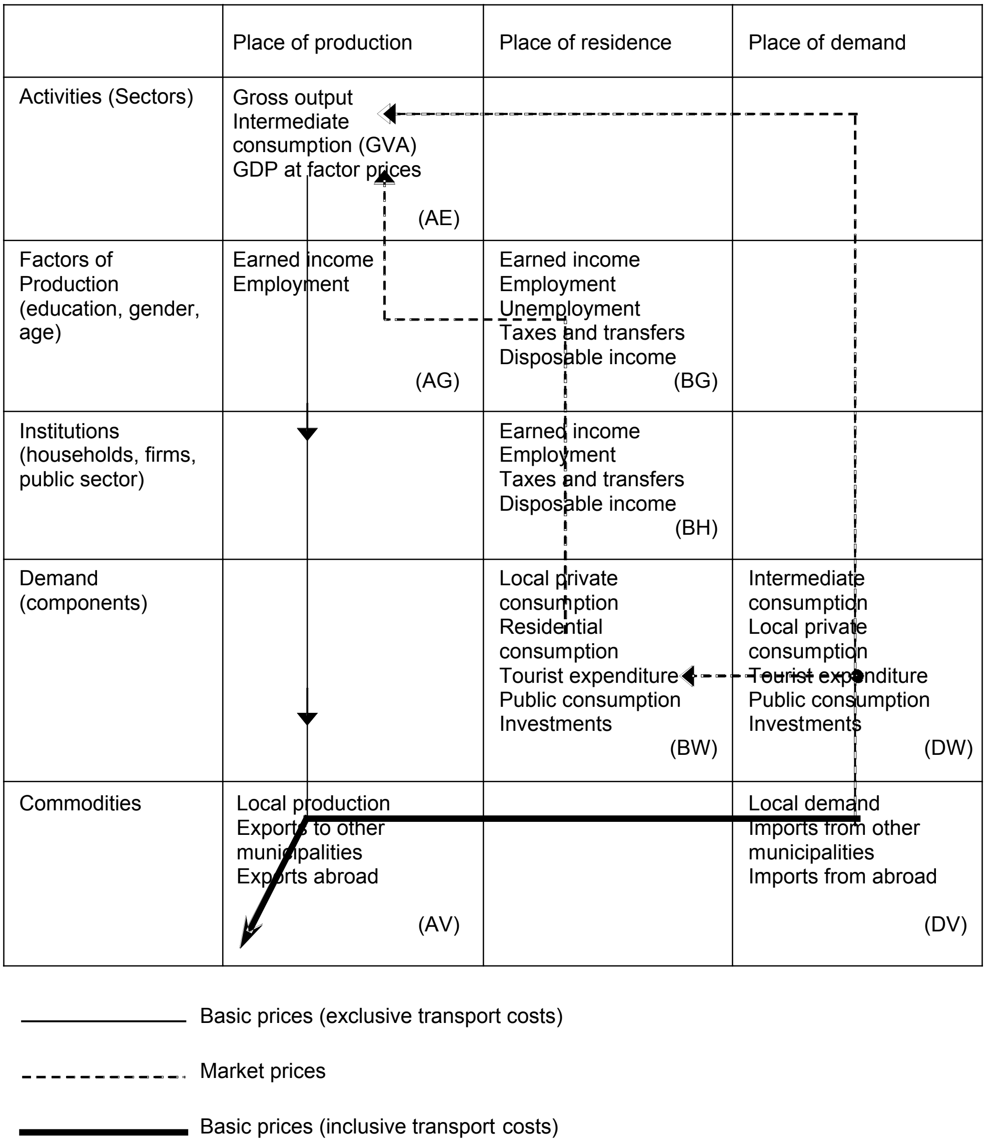


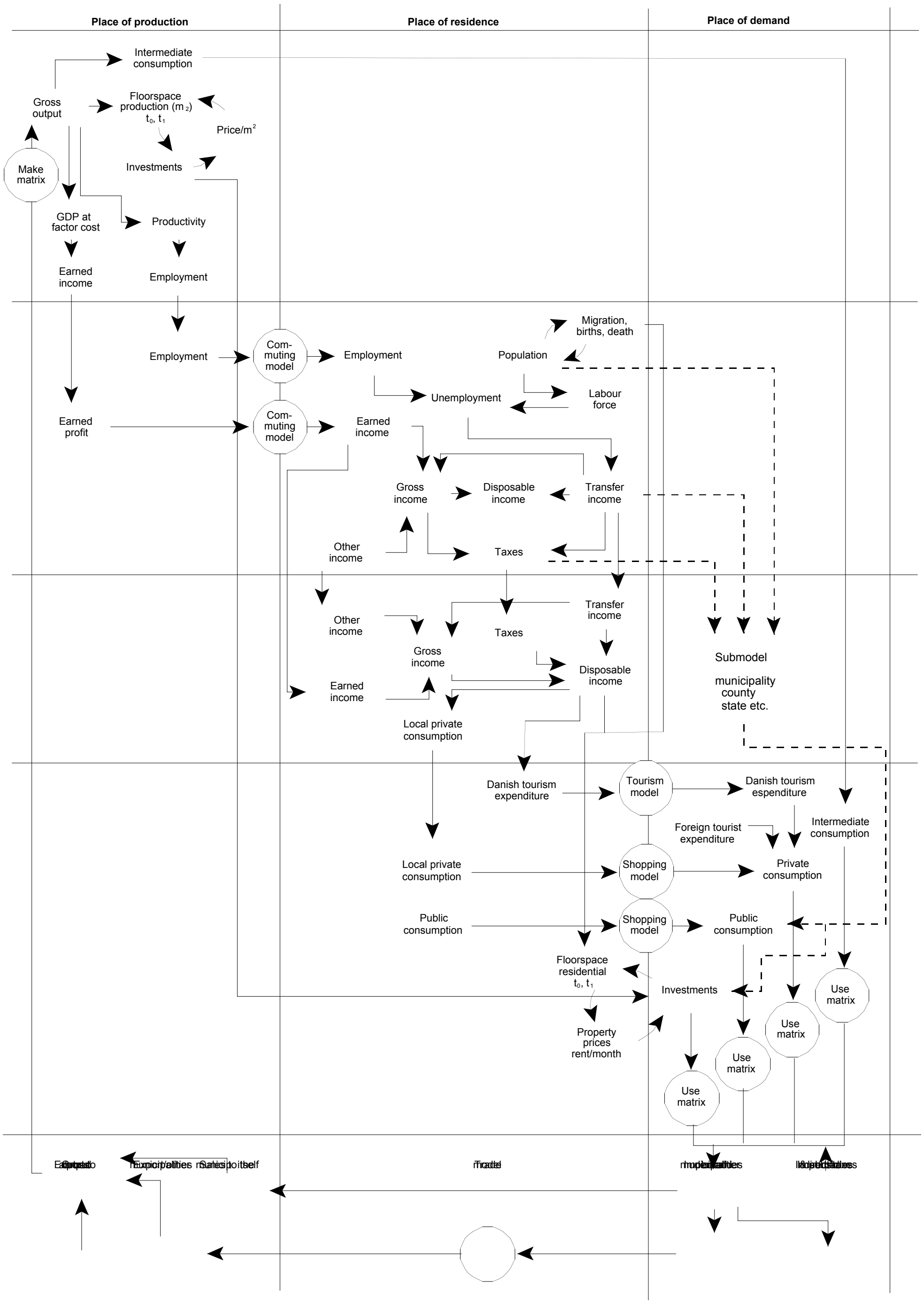
Figure 3. Simplified version of LINE: the real circle

	Place of production	Place of residence	Place of demand
Activities (Sectors)	Gross output Intermediate consumption (GVA) GDP at factor prices (AE)		
Factors of Production (education, gender, age)	Earned income Employment (AG)	Earned income Employment Unemployment Taxes and transfers Disposable income (BG)	
Institutions (households, firms, public sector)		Earned income Employment Taxes and transfers Disposable income (BH)	
Demand (components)		Local private consumption Residential consumption Tourist expenditure Public consumption Investments (BW)	Intermediate consumption Local private consumption Tourist expenditure Public consumption Investments (DW)
Commodities	Local production Exports to other municipalities Exports abroad (AV)		Local demand Imports from other municipalities Imports from abroad (DV)

——— Constant prices

- - - - - Current prices

Figure 4. The LINE model



The full model, shown in Figure 4, is described in Madsen et al. 2001a, where a more detailed treatment of the structure and the equations in LINE can be found, including a technical description of the solution routines.

3.3 Tourism in LINE

The LINE model is composed of several sub-models, for example, a commuting sub-model, a shopping sub-model, a tourism sub-model and a trade sub-model. In this section the tourism sub-model is described in detail.

The tourism sub-model (Zhang 2001) is integrated into the LINE model as tourism consumption, which covers both domestic tourism and foreign tourist expenditure in Denmark. Foreign tourism and domestic private tourism are a part of private consumption. Business tourism is a part of intermediate consumption. Domestic private tourism expenditure is determined by disposable income of residential households and by the price of the Danish tourism product in relation to the foreign tourist product. Domestic business tourism is determined by Gross Output by sector and sector specific commodity shares. Foreign tourists' consumption, which is divided into ordinary (overnight stayers) tourism and same day tourism, is determined alone by the price of the Danish tourism product in relation to the foreign tourist product.

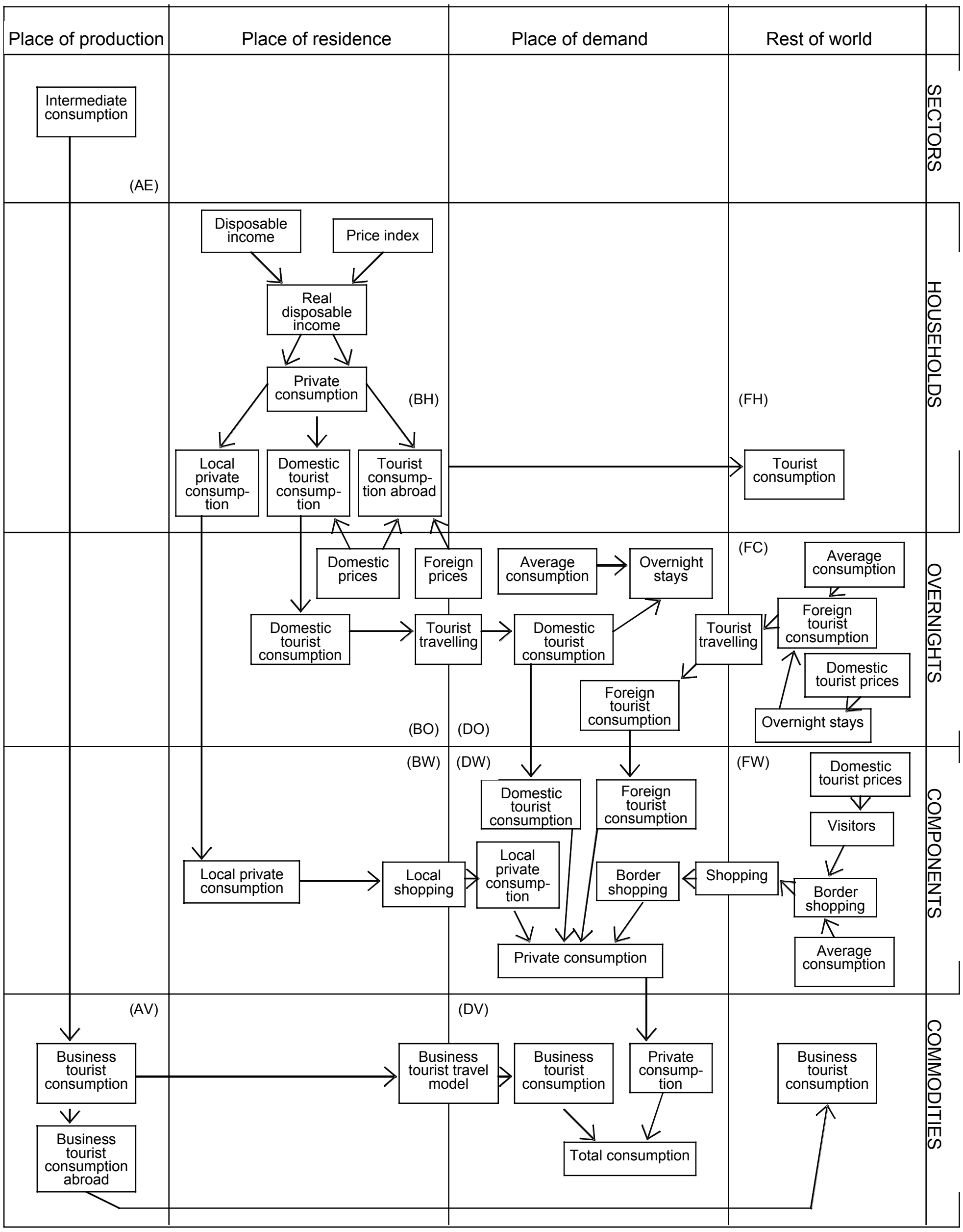
The model includes a division of tourists by nationality and type of overnight stay (camping, hotel etc). In its present form the model does not include modal choice, though work is currently being undertaken on linking LINE to a traffic model (and an environmental impact model), through a link model MERGE (Madsen & Jensen-Butler 2003)

In conclusion, the model for private consumption is composed of five sub-models: 1) residential local private consumption, 2) Danish domestic tourist consumption, 3) Danish tourist consumption abroad 4) foreign ordinary tourist expenditure in Denmark, and 5) foreign same-day tourist expenditure in Denmark.

Local demand for commodities related to private consumption is determined by adding private consumption by residents and tourist expenditure by Danes and foreigners. Danish consumption abroad does not of course affect local consumption. Figure 5 shows the flows of the tourism sub-models in LINE. The model is short and medium term. In the long term a surplus on the tourism account will of course influence the balance of payments and if exchange rates are flexible, adjustments will occur

The tourism sub-model for domestic private tourism starts from BH in Figure 5, where disposable income is the starting point. Disposable income of households generates both local private consumption and Danish tourist expenditure, which covers both domestic tourist expenditure and Danish tourist expenditure abroad. Local private consumption is distributed by the consumption component (BW), and then is transformed by the shopping model into the place of demand (DW). The distribution of tourism expenditure between home and abroad is determined by relative prices. Danish tourist expenditure in foreign countries is directly incorporated into total private consumption and imports from abroad (FH). The Danish domestic tourist expenditure is distributed to the overnight forms (BO). Then it is transformed by the tourism model to the place of demand (DO). Eventually, the Danish domestic tourist consumption is distributed by the consumption component (DW) and incorporated into total private consumption.

Figure 5. The private consumption/tourism sub-model



Domestic business tourism expenditure receives special treatment, as business travel expenses are a part of intermediate consumption by industry and place of production (AE). Modeling of business travel starts as intermediate consumption by sector and then is distributed by commodity (AV). It then goes through a tourism travel model from place of production to place of demand, DV, where business tourism activities take place. The number of overnight stays (assuming that there is data on average consumption) is determined as a function of demand for business tourism.

Foreign tourist expenditure contains both expenditure from overnight visitors (FO) and same-day visitors (FW). The distribution of foreigners' tourism expenditure between home and abroad is determined again by relative prices. The foreign ordinary overnight tourist expenditure is distributed first to the overnight forms (DO), and then it is distributed to consumption by component (DW) and is incorporated into total private consumption. The foreign same-day tourist expenditure (i.e. border shopping) is only distributed by the consumption component (DW), and then joins total private consumption. Finally, private consumption by component is transformed into private consumption by commodity (DV).

As indicated above, there are two different types of tourism: Danish tourism (either at home or abroad) and foreign tourists (again, either at home or abroad). For Danish tourists, the primary decision to be made is the allocation of expenditure to tourism and to local consumption. Given the amount of tourist expenditure, Figure 6 shows how tourism expenditure is divided between expenditure at home and abroad. In this nested structure, shares are determined by relative prices. Foreign tourists face the same choice, though in the LINE model they begin lower down in the nested structure.

All the different parts of the private consumption are eventually joined into total private consumption as shown in Zhang & Madsen (2001), who provide documentation of modeling and data construction in relation to local private consumption and tourism.

3.4 Specifying the concrete LINE model used to analyze tourism

Modeling tourism is undertaken at county level. This means that we use the county model for the tourism impact analysis, as the tourism data is assigned to the regions of the Danish counties, not to the municipalities. The industries used in the tourism model are aggregated into 13 sectors. There are 70 factors of production by education group (by sex (2), age (7) and education (5)) and four household types. The components of private consumption are aggregated to 12 groups. The collective governmental consumption components are based on eight groups. Finally, 25 commodities are employed. In the tourism model there are four foreign nationalities (German, Norwegian, Swedish and other) and six types of overnight (business hotel, private hotel, camping, youth hostel, summer cottage, other).

4. Modeling tourism, transport and the regional economy

Application of LINE permits analysis of the consequences for tourism and for the regional economy of any change in the transport system which affects the costs of transport. This includes road pricing, as described earlier, but can also include the construction of new infrastructure or changes in pricing of use of existing transport infrastructure.

In the present paper, as noted above, a specific example of road pricing is presented: the consequences of a major change in pricing policy for use of transport infrastructure is taken as a special case of road pricing. The example is that of the Danish Great Belt fixed link, whose location is shown in Figure 1. (See also Jensen-Butler & Madsen 1996a, 1996b.) This fixed link, both road and rail is 16 km long and at present tolls are charged for passage of vehicles. These tolls are substantial, being of the order of US$30 single for a car and five times this amount for a lorry. For rail passengers, tolls are not charged, though the railway company pays a fixed annual amount to the company owning the fixed link, which affects ticket prices. There is at present a proposal to reduce tolls to zero, and several studies are being undertaken to assess the regional economic impacts of such a policy (Madsen et al 2002).

Two further cases will be examined in the near future. The first is the construction of a new fixed link between Denmark and Germany, across the Femern Belt (Jensen-Butler & Madsen, 1999), which will reduce travel time costs between the two countries substantially and which will be particularly interesting in the analysis of German tourism in Denmark. The second is the development of a satellite and GPS-based road pricing system covering the whole country (Jensen-Butler & Madsen 2002, see also section 2.1).

4.1 Inputs to the model concerning transport

The present version of LINE is based on exogenously given interregional transport costs. In the longer term, the aim is to establish interaction between LINE and the Danish National Transport model, so that calculation of transport costs becomes endogenous. The matrices used here show the travel impedance between the 16 counties (*amter*) in Denmark in two different scenarios (with the present tolls on the Great Belt link and with zero tolls).

Two different sets of travel costs are used for tourist travel. First, for more informal family based tourism, not involving hotels (typically camping, summer cottages, family visits etc), low value car rates are used: US$8.3/hour and US$0.25/km. Second, for business and hotel based tourism low value truck rates were chosen, reflecting the use of public transport. Here the rates used are: US$37/hour and US$0.35/km.

The impedance is minimized with regard to the cost and the length and time matrices corresponding to the path when minimizing the cost. A digital map of Denmark (Vejdet DK) has been used for the calculation, where the network consists of 100,031 links and 79,476 nodes.

4.2 Direct changes in transport costs

Transport costs are based upon both time and distance where the generalized cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links.

Figure 7 shows the Danish regions (counties) used in this study. Note that two municipalities or districts (*kommuner*), Copenhagen and Frederiksberg, have the status of counties. In terms of tourist sector activity, Sønderjylland is an important tourist destination, especially for Germans and for one-day tourism. Camping and summer cottages are important here. In Nordjylland camping and summer cottages are important and Norwegian and Swedish tourists are well represented. The island of Bornholm has an important tourist sector, where both camping and hotels are important, as are German and Swedish tourists.

Finally, Greater Copenhagen (Københavns amt, Frederiksborg amt, Roskilde amt and the two municipalities of Copenhagen and Frederiksberg) is an important tourist destination, based on hotels, and business tourism is important here. Swedish and German tourists are strongly represented and one-day tourism is important.

Table 1 shows the percentage changes in generalized transport costs between Danish regions as a result of elimination of tolls on the Great Belt link. The overall result is of course a decline in transport costs. However, some regions do not experience a decline in costs. North and North West Jutland for example, have unaltered transport costs, as the route between these regions and Copenhagen does not use the Great Belt link, but is assumed to use ferries instead. This means that the reductions in transport costs are to be found mainly in mid- and southern Jutland. For foreign tourists and for domestic east-east and west-west tourism these reductions have little consequences, as they in general do not use the Great Belt link when they travel to Danish tourist destinations.

Figure 7. Danish counties

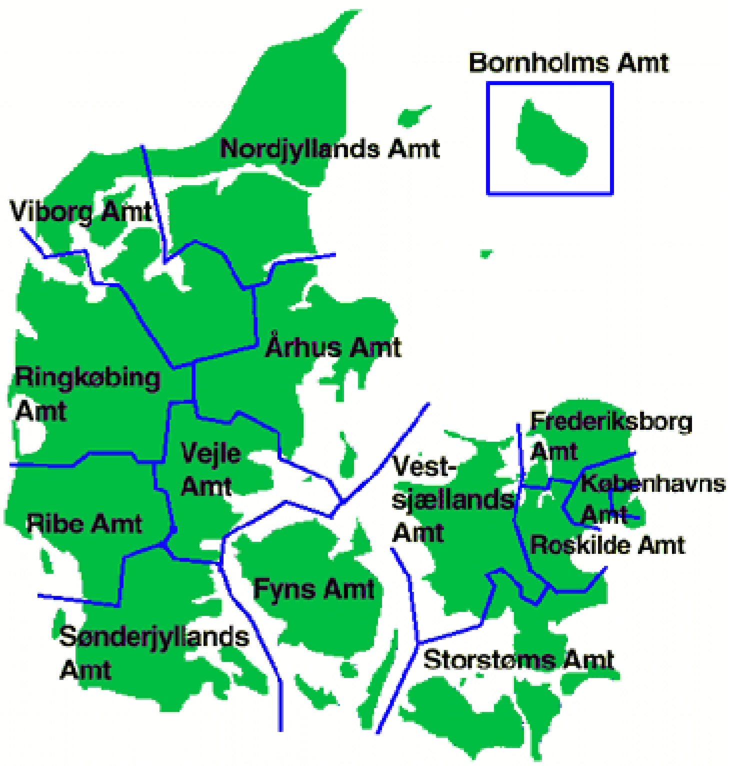


Table 1 Percentage changes in transport costs with road pricing

	Copen M	Frberg M	Copen C	Frborg C	Rosk C	Wzeal C	StStrm C	Bornh C	Fyn C	SJutl C	Ribe C	Vejle C	Ringk C	Aarhus C	Viborg C	NJutl C
CopenM	0	0	0	0	0	0	0	0	-30	-21	-20	-24	-14	0	-7	0
FrbergM	0	0	0	0	0	0	0	0	-31	-21	-20	-24	-14	0	-7	0
CopenC	0	0	0	0	0	0	0	0	-31	-21	-20	-24	-14	0	-7	0
FrborgC	0	0	0	0	0	0	0	0	-29	-20	-20	-23	-12	0	-5	0
RoskC	0	0	0	0	0	0	0	0	-36	-23	-22	-27	-19	0	-12	-3
WzealC	0	0	0	0	0	0	0	0	-47	-27	-26	-33	-24	-2	-15	-4
StStrmC	0	0	0	0	0	0	0	0	-25	-20	-19	-23	-18	-2	-12	-4
BornhC	0	0	0	0	0	0	0	0	-11	-9	-9	-10	-6	0	-3	0
FynC	-30	-31	-31	-29	-36	-47	-25	-11	0	0	0	0	0	0	0	0
SjutlC	-21	-21	-21	-20	-23	-27	-20	-9	0	0	0	0	0	0	0	0
RibeC	-20	-20	-20	-20	-22	-26	-19	-9	0	0	0	0	0	0	0	0
VejleC	-24	-24	-24	-23	-27	-33	-23	-10	0	0	0	0	0	0	0	0
RingkC	-14	-14	-14	-12	-19	-24	-18	-6	0	0	0	0	0	0	0	0
AarhusC	0	0	0	0	0	-2	-2	0	0	0	0	0	0	0	0	0
ViborgC	-7	-7	-7	-5	-12	-15	-12	-3	0	0	0	0	0	0	0	0
NjutlC	0	0	0	0	-3	-4	-4	0	0	0	0	0	0	0	0	0

4.3 Consequences for the price of the tourism product

The effects are somewhat different for Danish tourists in Denmark and for foreign tourists in Denmark. The price of the tourism product has two components. First, the prices of commodities at the place of demand (tourist activity: hotels, restaurants etc) and second, the cost of transport involved in reaching the place of demand from place of residence, accounted for at place of residence. In general, the prices of commodities in Denmark at place of demand will fall with zero tolls on the Great Belt, as the costs of interregional trade fall. This favors especially the tourism product in the central belt of Denmark, where cost reductions are greatest. If we examine the price of the tourism product including transport costs, this effect should be reinforced. This double effect applies only to Danish tourists in Denmark. Foreign tourists will experience only the price reduction on goods and services.

Column 2 in Table 2 shows the price changes for Danish tourists arising from changes in the prices of goods and services created by elimination of Great Belt tolls. The main gains will be in Greater Copenhagen, reflecting the reduction in transport costs for industrial products, produced in Jutland. Likewise, there are above average reductions in Ringkøbing, Viborg and Sønderjylland, reflecting imports of intermediate products and service across the Great Belt from eastern Denmark. The first column shows price changes for products demanded by foreign tourists in Denmark at place of demand. Here again, Greater Copenhagen gains most, as do Sønderjylland and Ringkøbing, both areas benefiting from lower transport costs on commodities and service between east and west Denmark.

Table 2. Consequences for prices of the tourism product of elimination of the tolls on the Great Belt link (in current 1998 prices)

	Foreign tourists	Danish tourists	
County (amt)	By place of demand	By place of demand	By place of residence
Copenhagen kommune	-0.28	-0.26	-1.80
Frederiksberg kommune	–	–	-1.62
Copenhagen amt	-0.25	-0.15	-3.47
Frederiksborg amt	-0.25	-0.26	-5.56
Roskilde amt	-0.23	-0.20	-0.53
Vestsjællands amt	-0.18	-0.16	-2.13
Storstrøms amt	-0.15	-0.15	-5.43
Bornholms amt	-0.17	-0.17	-0.32
Fyns amt	-0.13	-0.14	-1.41
Sønderjyllands amt	-0.20	-0.19	-4.92
Ribe amt	-0.16	-0.16	-3.30
Vejle amt	-0.12	-0.12	-4.64
Ringkøbing amt	-0.20	-0.19	-2.23
Århus amt	-0.08	-0.08	-3.69
Viborg amt	-0.16	-0.17	-5.87
Nordjyllands amt	-0.15	-0.13	-2.19
Denmark	-0.20	-0.16	-3.03

Source: Model calculations from LINE.

As noted above, our initial expectation was that when Danish tourists' travel patterns were included, prices would fall in central regions including central and southern Jutland, together with Greater Copenhagen, as these regions would benefit primarily from the changes in tolls on the Great Belt. It was expected that more peripheral regions, such as Nordjylland, Viborg and Bornholm would experience fewer benefits. This pattern is rather unclear in the last column of Table 2. Bornholm and Nordjylland conform to expectations for peripheral regions, and Sønderjylland, Vejle, Ribe and the outer areas of Greater Copenhagen do well, as is to be expected. Unfortunately, there are a number of anomalies, such as central Copenhagen, Fyn and Ringkøbing, which should be greater, and Storstrøm and Viborg, which should be smaller. These anomalies probably arise because of the unsatisfactory nature of the data set used to calibrate the tourist origin-destination model, which will be remedied by accessing a superior data set. A second problem is that the model at present does not permit substitution of destinations, as relative prices change.

4.4 Consequences for tourists' consumption

Price changes have consequences for tourist's consumption, which depend upon price elasticity. For Danes travelling abroad, the national macro-economic model ADAM provides estimates of import elasticities. Jensen (1998) has estimated price and import elasticities for foreign tourists in Denmark, shown in Table 3.

For foreign tourists, the elasticity is multiplied by number of tourists by nationality and by type of overnight stay, assuming that the elasticity is the same for all types of stay, including one-day tourism. For Danish tourists abroad, a reduction in domestic price levels will reduce demand for tourism abroad, and thereby creating a reduced import. The high price elasticities for German tourists should be noted. In light of the price changes shown in Table 2, and the elasticities shown in Table 3, changes in tourists' demand are shown in Table 4.

As the table shows, the overall effects on tourist consumption by place of demand are 0.6% for Danish tourists and 0.2% for foreign tourists, who alone gain advantage of price changes in commodities and services at place of demand. These magnitudes are intuitively of the correct order. What the first and last columns show is the extent to which interregional trade spreads the benefits evenly. The middle column reflects the results and problems of the last column of Table 2. As expected, Sønderjylland, Ribe and Vejle together with parts of Greater Copenhagen, experience above average growth in consumption, while Northern Jutland and Bornholm have lower than average growth. The anomalies again are Viborg and Storstrøm (too high) and Ringking and Fyn (too low).

4.5 Consequences for production, income and employment

An increase in tourists' demand will result in a growth in local demand, which translates into changes in production at place of production, depending on the regional pattern of input supply to tourist-related activities. These changes in turn translate into changes in income and employment by place of residence. The changes also depend on patterns of commuting for people working in tourist-related activities. The principal results are shown in Table 5.

Unlike the earlier tables, Table 5 includes the total effects (direct, indirect and induced, as well as changes in competitiveness). The table shows that local demand in relative terms (per 000) at place of demand grows most in Southern and mid Jutland (Sønderjylland and Ribe), as well as in Nordjylland. Bornholm also benefits, but this is related closely to the disproportionately large tourism sector on that island. The absolute effects can be seen in the table. It is estimated that eliminating tolls on the Great Belt link will create 193 jobs, a credible order of magnitude, distributed by place of residence and place of production as shown in the table. Growth of GDP (million DKK) follows a pattern similar to that of employment growth, as does disposable income. The effects in Sønderjylland and Nordjylland are notable, these regions both having important tourism sectors.

Table 3. Price and import elasticities for tourism

	Price elasticity	Import elasticity
Germany	-2.02	-
Sweden	-0.04	-
Norway	-0.55	-
Others	-1.00	-
Danish tourists abroad	-	0.1

Table 4. Percentage changes in tourists' consumption (in fixed prices)

County (amt)	Foreign tourists	Danish tourists	
	By place of demand	By place of residence	By place of demand
Copenhagen kommune	0.2	0.4	0.8
Frederiksberg kommune	–	0.7	-
Copenhagen amt	0.2	0.7	0.5
Frederiksborg amt	0.0	1.9	0.7
Roskilde amt	0.2	0.1	0.6
Vestsjællands amt	0.2	0.6	0.6
Storstrøms amt	0.2	1.0	0.6
Bornholms amt	0.2	0.0	0.6
Fyns amt	0.2	0.2	0.7
Sønderjyllands amt	0.4	0.7	0.5
Ribe amt	0.3	0.7	0.7
Vejle amt	0.1	0.9	0.8
Ringkøbing amt	0.3	0.3	0.6
Århus amt	0.1	0.9	0.6
Viborg amt	0.2	1.3	0.8
Nordjyllands amt	0.1	0.5	0.6
Denmark	0.2	0.6	0.6

Source: Model calculations from LINE.

The findings of Table 5 are the result of a combination of a number of different factors. First, changes in competitiveness of different tourist destinations, as shown by the price changes in Table 2. Second, it is a consequence of the composition by Danish region of foreign tourists by country of origin and the different price elasticities which apply to these. Third, it depends on the relative importance of the demand for tourism in total local demand, by region. First, South and mid Jutland gains most from the price effects, while North and West Jutland gains little. Second, assuming a simple distribution of foreign tourists according to the following pattern: Germans mainly in south and mid Jutland, Norwegians in Northern Jutland and Swedes in Copenhagen, then the relatively high price elasticities for Germans and low price elasticities for Swedes and Norwegians (Jensen, 1998), will benefit even further south and central Jutland, rather than elsewhere. Third, counties where tourism is an important component of the regional economy include: Bornholm, Southern Jutland and Northern Jutland. They will experience greater regional economic consequences than others. Counties such as Vejle and West Zealand, while having a favorable location, have small tourism sectors, which means that the local economic advantage is limited. In the regional economy of Northern Jutland tourism is important, but the price effects and the price elasticity effects imply that there will be a reduction in benefits to an important sector.

Table 5. Consequences for demand, production, income and employment of elimination of Great Belt tolls (Units: million DKK, persons and per thousand in parentheses)

	By place of demand	By place of production		By place of residence	
	Local demand	GDP	Employment	Disposable income	Employment
Copenhagen kommune	18 (0.061)	7 (0.043)	21 (0.065)	2 (0.041)	14 (0.055)
Frederiksberg kommune	–	0 (0.013)	1 (0.017)	0 (0.037)	2 (0.048)
Copenhagen amt	9 (0.038)	5 (0.034)	15 (0.042)	3 (0.038)	15 (0.048)
Frederiksborg amt	6 (0.055)	2 (0.036)	8 (0.049)	2 (0.039)	10 (0.049)
Roskilde amt	3 (0.054)	1 (0.036)	5 (0.047)	1 (0.038)	6 (0.049)
Vestsjællands amt	5 (0.057)	2 (0.042)	7 (0.055)	1 (0.043)	8 (0.054)
Storstrøms amt	7 (0.103)	2 (0.065)	10 (0.091)	2 (0.064)	10 (0.084)
Bornholms amt	3 (0.211)	1 (0.133)	4 (0.172)	1 (0.132)	3 (0.167)
Fyns amt	10 (0.075)	4 (0.052)	16 (0.070)	3 (0.054)	16 (0.070)
Sønderjyllands amt	29 (0.317)	8 (0.187)	33 (0.258)	5 (0.191)	31 (0.243)
Ribe amt	8 (0.094)	2 (0.061)	10 (0.085)	2 (0.066)	10 (0.086)
Vejle amt	6 (0.049)	2 (0.038)	10 (0.054)	2 (0.044)	11 (0.058)
Ringkøbing amt	5 (0.054)	2 (0.035)	8 (0.051)	1 (0.040)	8 (0.052)
Århus amt	11 (0.057)	5 (0.045)	18 (0.056)	3 (0.045)	19 (0.057)
Viborg amt	6 (0.074)	2 (0.046)	8 (0.063)	1 (0.050)	8 (0.063)
Nordjyllands amt	16 (0.096)	5 (0.063)	22 (0.088)	4 (0.067)	22 (0.086)
Outside regions	0 (0.000)	0 (0.009)	0 (0.000)	0 (0.000)	0 (0.000)
Denmark	141 (0.076)	49 (0.051)	193 (0.070)	34 (0.054)	193 (0.070)

Source: Model calculations from LINE.

5. Conclusions

A model for the analysis of effects of changes in transport costs on the tourism sector has been presented. This model permits analysis of these changes in a systemic and theoretically coherent manner within a general equilibrium framework. Results from its application in Denmark have also been presented, where the change in transport costs arose from a specific form of change in road pricing, the elimination of substantial tolls on the major fixed link in Denmark, between the east and west parts of the country. Consequences for price changes in relation to the tourism product were calculated, by region, and using price elasticities for different groups of tourists, these price changes were translated into changes in consumption, again by region. These changes feed through into changes in local demand, employment, GDP and disposable income for each region, when the full effects are accounted for. The results obtained are in part at least interpretable. However, anomalies do arise, which relate to the data used in the tourism sub-model and which will be addressed through the future use of a superior data set.

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