SAM-K/LINE®_RHSA: Regional Economic Model for Healthcare and Labour Market

Healthcare economic extension of SAM-K/LINE®, version 2018

Nino Javakhishvili / nino.javakhishvili@crt.dk

18-09-2019

Centre for Regional & Tourism Research

Title:

SAM-K/LINE®_RHSA: Regional Economic Model for Healthcare and Labour Market

Healthcare economic extension of SAM-K/LINE®, version 2018

Authors:

Laura Virtanen and Nino Javakhishvili

Centre for Regional & Tourism Research (CRT)

Stenbrudsvej 55

DK-3730 Nexoe

Tel +45 5644 1144

Email: crt@crt.dk

www.crt.dk

Centre for Regional & Tourism Research is a centre for applied research and consulting on the development of peripheral areas and tourism targeting strategy and policy development at local, regional and international levels. CRT is located on Bornholm and has existed since 1994.

Index

Abbreviations

RHSA:	Regional Healthcare Satellite Accounting
CRT:	Centre for Regional and Tourism Research
SAM-K:	Social Accounting Matrix for (K) Municipalities
LINE:	Local INterregional Economic Model
IO:	Input-Output
CGE:	Computable General Equilibrium
HCP:	Healthcare Professionals

Overview

Centre for Regional and Tourism Research, in collaboration with Centre HR of The Capital Region of Denmark developed Regional Healthcare Satellite Accounting (RHSA) for Danish healthcare sector and labour market of healthcare professionals. RHSA is an economic extension for Regional Economic Model, SAM-K/LINE® that is developed, owned and operated by Centre for Regional and Tourism Research (CRT). The aim of the model is to provide a detailed quantitative framework for regional short- and long-term projections of the labour market supply and demand of health care professionals (HCPs) in Denmark. Although this project is built together with the Capital Region of Denmark, it is designed to simulate the entire country of Denmark, taking into consideration all five regions, 98 municipalities, and inter-regional linkages and flows.

SAM-K/LINE® is the SAM based IO-CGE model with a Keynesian income multiplier for Danish municipalities and is developed to assist the local and regional authorities for planning socioeconomic development in the administrative regions and municipalities in Denmark. The basic structure of LINE® has been documented in a number of scientific articles (Madsen, 2009; Madsen & Jensen-Butler, 2004 & 2005; Madsen & Zhang, 2010).

This technical documentation explains the RHSA extension of SAM-K/LINE® in detail - its data input, model structure, outputs and theoretical fundamentals.

1 Model Background

SAM-K/LINE®_RHSA model has been initially designed as a data-based analytical tool to project possible labour market imbalances for health care professionals, and to assist in qualifying the dialogue between The Capital Region of Denmark and educational institutions on the educational capacity in health science education programs. In addition, it allows the Danish regions to have a holistic perspective on the economic activity within general practice, home and residential care, and hospital departments, from which they can obtain information on, for instance, number and type of treatments, costs of treatments, employment by number of hours as well as number of people, by education type. In addition, the model gives an indication of the geographical and demographic differences in the level of health of the Danish population (subject to demand for different treatment/illness types). The projections of the model answer, for example, the following questions:

- Are educational institutions training too few or too many health professionals to provide the healthcare services for the citizens now and in the future?
- Can a balance be expected between supply and demand from both the public and private healthcare sector in the future, assuming that some HCPs will not

be working, some will find work in other sectors, work part-time, or move to other regions, etc.?

With these questions in mind, the SAM-K/LINE®_RHSA18 has been designed to include a regional labour market model for HCPs as well as a model for the demand of welfare services. The regional labour market model has a sub-model for the level of education and education activities of the population.

The projections and scenarios with the SAM-K/LINE®_RHSA18 are used to assess the medium-term education decisions in terms of dimensioning education programs on the basis of labour market balance for HCPs.

In order to ensure that the projections are empirically well founded and in line with demographic and economic trends, the RHSA model must, on the one hand, be able to predict the changes in the labour supply of HCPs and its connection to education activities, retirement schemes and behaviour. It is therefore essential to predict population structure as well as the age-dependent labour supply, in reference to retirement patters as well as the interaction between ongoing education activities and the resulting education structure of the population. On the other hand, the RHSA model must be able to capture and predict the demand for healthcare services, and in turn the demand for HCPs, all as a function of regional age and social structure, size of the population, the health status of the population, treatment patterns, as well as the general development of production, income and consumption. Finally, predictions and scenarios of the labour market for HCPs take into account macroeconomic developments in Denmark in regard to the developments abroad, the changes in fiscal policy and expected governmental expenditures, as well as general long-term projections for demographic development and population growth.

1.1 Empirical Relevance of the Model

In a welfare country like Denmark, health care expenditures take up a substantial share of governmental budget. In fact, health care spending total 10.4 percent of gross national product in Denmark in 2016, amounting to approximately 37,300 Danish Krone per capita in the same year (OECD Statistics, 2018). As such, ensuring the efficient allocation of resources within the health service sectors is in the best interest of the state not only from a welfare perspective, but from a budgetary perspective. Similarly, an imbalance in the workforce for health personnel is an important policy issue that not only requires acknowledgement, but also intervention. Health and social services employ a substantial share of the total workforce within Denmark as well as other European countries, comprising of approximately 14.5 percent of total employment in Denmark in 2016. However, a shortage of health personnel is observed throughout Europe, including Denmark, while demand continues to grow in line with demographic factors, such as population growth and ageing (SAM-K/LINE®, 2018; European Commission, 2014).

Even with evident modernization and rapid technological development, the labour force for health care personnel (HCPs) is undoubtedly the key component behind effective and sustainable health systems. However, ensuring an adequate supply of skilled and unskilled medical personnel has proven difficult on a global scale. This can be due to several reasons, but one notable explanation is the lack of quantitative forecasting models which capture the demand for health in all its complexity, including demographic drivers, such as population health, ageing and retirement patterns, technological change, and changing disease patterns to name a few. Another reason why imbalances in the labour market for health personnel are difficult to eliminate is due to the mere length of education programs for doctors and other health personnel, and thus changes in educational capacity can take a relatively long time to have any effect on labour force (Zurn, P., Dal Poz, M. R., Stilwell, B., and O. Adams, 2004).

A labour market imbalance arises when the quantity demanded of a certain skill by employers diverges from the quantity supplied by the qualified workforce, thus creating a disequilibrium at the current market conditions. Alongside rising incomes and standards of living around the world, individual public consumption for health has been growing, as observed in Denmark as well (The European Commission, 2014). This can be largely explained by demographic factors, such as growing and ageing populations that demand more health services. Rising incomes and higher standards for healthcare are in themselves other factors affecting the rise in individual governmental consumption for health and care, and the positive correlation between national income and national healthcare expenditures has been documented in numerous studies. In line with rising demands, it has been argued that the most healthcare systems in developed countries fail to deliver services of health and care to a "satisfactory" standard, often reflecting a limitation in financial budgets and suboptimal use of resources (Rutten, M. & Reed, G., 2009). As a response to rising health demands and apparent labour force imbalances in developed countries alike, governments are increasingly interested in optimizing their resource planning systems to ensure their future workforces meet population health demands.

In Denmark, health care is a public good, largely financed through taxes and administered by the regions and municipalities through top-level planning[1]. This system is designed to ensure equal access to healthcare for all Danish citizens, regardless of location or household income. However, as also seen in many other OECD countries, the future labour market for HCPs in Denmark is agile. As reported by Madsen and Jensen (2017), the health care sector in Denmark is expected to face a capacity shortage, in which demand is expected to exceed supply of skilled health personnel out to 2025. However, there are considerable differences amongst different fields and levels of

[1] Danish Healthcare System is unique, free and accessible for all citizens. It is publicly financed and operates across the three political and administrative levels: the state, the regions and the municipalities. More about it can be read in an overview of the system by the Ministry of Health https://www.healthcaredenmark.dk/media/1479380/Healthcare-english-V16-decashx-3.pdf

education, as well as amongst different regions in Denmark. Most prominently, the demand for health personnel with PhDs or higher medical qualifications is expected to increase quicker than supply, while with some qualifications, such as physiotherapists, supply is expected to exceed demand out to 2025, resulting in unemployment (Madsen, 2016; Madsen and Jensen, 2017).

2 Data

The special version of SAM-K/LINE®_RHSA is built from extended sets of data, which have been constructed into social accounting matrices for municipalities (SAM-K) following the so-called two-by-two-by-two framework. As opposed to the general LINE® model, SAM-K has been extended with data matrices to support the sub-models for individual governmental consumption for healthcare and education. The model further scales to the macroeconomic model ADAM (Annual Danish Aggregated model) as well as the population forecast as projected by Statistics Denmark. Key data is listed and summarized in Table 1 below.

Table 1: Data input in the SAM-K/LINE®_RHSA18

Data	Description	Source
1. Register data	Person data, company data, income data	Statistics Denmark
2. National Accounts data	Transactions, product flows and key economic indicators at the national level, including production, employment, gross value added, consumption, imports and exports, gross fixed capital formation, etc.	Statistics Denmark
3. Municipality Accounts data	Current and capital accounts of the Danish Municipalities	Statistics Denmark
4. TØBBE survey data	Tourism activity and consumption in Denmark	Visit Denmark
5. ADAM forecast data	Annual national forecast of the Danish Economy. Takes into account the assumptions of macroeconomic development and expected results from the state reforms and investments.	Statistics Denmark
6. Population projection data	Population projections in Denmark until 2065 at the national level, and until 2045 at the regional and municipal level. Key data includes expected population growth, based on assumptions on fertility, mortality, and net-migration.	Statistics Denmark (in collaboration with the DREAM model).
7. Labour Market data	Quarterly unemployment by municipal level.	Statistics Denmark (Statistiksbanken.dk)

8. Doctor authorization data	Authorisation for qualified special doctors, showing the authorization doctors have been trained into.	The Danish Health Authority (SDS)
9. National Patient Register (LPR) data	Consumption of hospital services (number and cost of services) by type of treatment.	The Danish Health Authority (SDS)
10. Health Insurance register (SSSY) data	Consumption (number of visits and cost) and recipients of health practice services including visits to GPs, dentists, specialized practitioners, chiropractors, etc.	The Danish Health Authority (SDS)
11. Home care data	Consumption (number of visits and cost) and recipients of home nursing services.	Statistics Denmark
12. Capital Region hospital data	Employments in hospital departments within the Capital Region, showing who (persons with specific qualifications) are employed in which organizational units.	The Capital Region of Denmark, Centre for HR

The data unique to the special version SAM-K/LINE®_RHSA18 is in categories 8-12 in Table 1 and has been used to model the demand for healthcare services, and in turn the demand for health personnel. The hospital data from The Capital Region of Denmark was received in accordance with collaboration efforts and shows the distribution of hospital employees into different organizational units (or hospital departments) within the hospitals in the region. Industry group data provided by Statistics Denmark does not include a disaggregated hospital industry, so for the sake of the present model it was essential to receive organisational data from the Capital Region in order to distribute persons and activities at the disaggregate level (which is then scaled to the hospital industry total as provided by Statistics Denmark).

The SAM-K/LINE® model system has adjustable aggregations for sectors, population factors (gender, age, education, socio-economic status), household types and commodities to allow for detailed analysis, depending on the focus in question. The special version of SAM-K/LINE®_RHSA18 has a unique level of aggregations emphasizing activity and consumption within the health care industry, as well as the demand and supply of HCPs. Namely, the model includes 47 fields of education at 8 different levels: basic education, vocational and short-cycle higher education ("EFU" and "KVU"), medium-cycle higher education ("MVU"), professional bachelors, long-cycle higher education (“LVU”) and in addition, special doctor training/authorisations. Out of the 47 different fields of education, only 7 of them are non-health related, comprising of aggregated groups for all other educations at each level, as well as a group for uneducated and/or undisclosed. The model includes a total of 22 doctor authorisations, making it to our knowledge, the most comprehensive health-related education-based model for labour market in Denmark.

In addition to education, another noteworthy aggregation to mention is the model’s sectoral aggregation. The RHSA version of LINE® models 57 different sectors in the economy, of which 22 are sub-hospital industry groups, such as orthopaedics and paediatrics, 8 of which are physician practice industry groups, such as psychology practices and dental practices, and 5 of which are within the industry group of home and residential care. See Appendix A for a list of unique aggregations used in the RHSA version of SAM-K/LINE®.

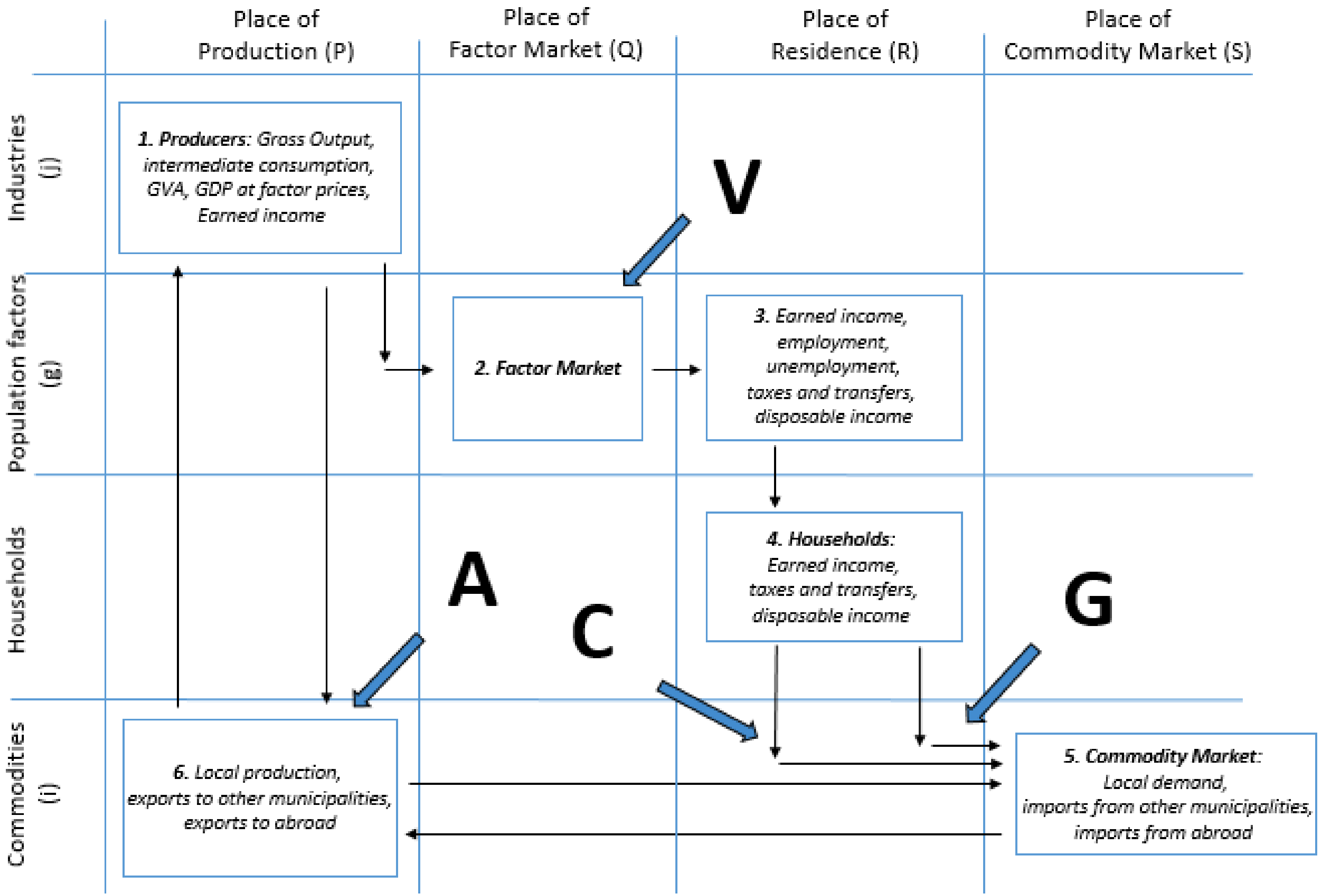
3 Model Structure: Overview

The RHSA version of LINE® is based on the two-by-two-by-two framework, as introduced by Jensen-Butler and Madsen (2004) and Madsen (2008), by which the model incorporates two sets of actors (production units and institutional units), two types of markets (commodities and factors) and two locations (origins and destinations). The basis for this principle originates from the Leontief and Isard interregional input-output methodology (Leontief, 1936, 1966; Isard,1951), and the Miyazawa extended demographic quantity model (Miyazawa, 1966, 1968, 1976). The model has a spatial geographical dimension (at the regional and municipality level), further distinguishing between place of production (where people work and produce goods and services), the place of residence, and the place of the commodity market. In addition, the model contains a four-fold division into SAM-actors: 1) production sectors (J), 2) population factors such as age, gender, education and social status (F), 3) household types (H), and 4) types of commodities (V).

The LINE® model is based on use-, trade-, and make-matrices following a commodity-by-industry approach, a method also documented by Miller and Blair (2009).Therefore, LINE® is considered different from the typical multi-regional input-output models, where economic interactions typically take place between sectors. However, the structure of LINE® also reflects many standard macroeconomic and demographic models, in that it includes a quantity input-output model as well as a Keynesian income multiplier model at its core, both of which have been inserted into the two-by-two-by-two structure. The Input-Output methodology, which was first introduced by Wassily Leontief in 1936 and has since been applied and extended into a vast variety of economic models, allows for the calculation of direct, indirect and induced effects in the general as well as the RHSA version of LINE® through the data matrices which feature the intra-and inter-regional linkages between sectors and between sectors and final demand.

In order to assess the supply and demand of healthcare professionals (HCPs) in Denmark, the RHSA version of SAM-K/LINE® contains a quantity model for the demand and supply of commodities and labour, a cost-price model for the production of goods and services as well as labour (in current prices), and a stock-flow model featuring population changes by education. Following the works of Madsen and Jensen-Butler (2004) and Madsen (2008), the structure of the quantity model is depicted in Figure 1. In the RHSA version of LINE®, a Leontief and Miyazawa quantity model has been expanded to account for the specific nature of the health care sector and the HCP labour force, such as the demand of HCP labour subject to demand for healthcare treatments.

Figure 1: Description of RHSA in the local economy based on the Leontief and Miyazawa demographic economic model in the 2-by-2-by-2 framework



SOURCE: SAM-K/LINE®

As depicted by Figure 1 above, there are two actors, producers and households, and two markets, commodity and factor markets, in the local economy. Between the two actors and two markets, flows (trade, commuting and shopping) with both geographical and SAM origins link the actors and markets together, creating the two-by-two-by-two framework. In the structural depiction above, producers (1) belong to the Pj-cell at the upper left corner of the diagram at the place of production and within industries; as an example, a maternity ward within Herlev hospital within The Capital Region of Denmark. By design, production (e.g. maternity ward treatments/births) takes place here. Households (4), on the other hand, belong to the Rh cell at the place of residence. Households are categorized by type, such as families with and without children.

The commodity market (5) at the Si-cell is at the place of sales (where commodities sold and received), and at the SAM-axis for commodities. In the case of healthcare and education, commodities refer to healthcare services by type of treatment and education by type (field and level) of education, whereas the place of sale/commodity market is where the treatment or education is being received (e.g. birth at Herlev Hospital or Midwifery education at Copenhagen University). Lastly, the factor market (2) belongs to the Qg cell at the place of the factor market and by population factors, which in the present version of the model include gender, age, education and socioeconomic status. The factor market typically implies to the place where contacts and contracts between the employer and employee take place.

The clockwise order in the diagram space in Figure 1 represents a typical Keynesian model. The circle starts with production (1) which creates factor incomes (in basic prices) and employment, which then move from the sectors to population factors (g), still at the place of production. Through a commuting model, the factors of production (land, labour, capital), and therefore both factor incomes and employment, move from the place of production to the place of residence (2), still by population factors (g).2 Commuting costs are paid for by factor incomes. Employment and resulting unemployment are determined at the place of residence (B) by population factors. At the same space, disposable income is generated by subtracting taxes and adding other transfers and incomes. Further along in the clockwise order, private consumption in market prices, which come from disposable income, is determined at the place of residence by household (4). Through a shopping model, private consumption then moves to the place of the commodity market. With the use matrix, local demand for commodities (in basic prices) can be derived from intermediate consumption, public consumption and investments at the place of the commodity market. Commodity taxes and trade margins are subtracted during the transformation from market prices to basic prices. At the place of the commodity market, imports from abroad and local

[2] The place of factor market (2) is omitted from the model, as the factor market is poorly defined from a data point of view. The labour (factor) market is therefore assigned to the place of residence.

production meet local demand, and further, through the trade model, inter-regional exports are determined, now at the place of production. Gross output by commodity can now be determined by further exports abroad, which come in exogenously. A reverse make matrix returns production from the place of production by commodity to place of production by sector, which concludes the circle (Jensen-Butler & Madsen, 2004).

In addition, Figure 1 depicts flows between the actors and markets, as indicated by the A-, V-, C-, and G-matrices. The A-matrix depicts gross output by industry at the place of production and captures the "indirect effects" between production and intermediate consumption. The V-matrix shows labour demand. The C-matrix shows private consumption, and together with the V-matrix, they capture the "private consumption induced effects" between production and households. The G-matrix depicts individual governmental consumption, and together with the V-matrix, they capture the "individual governmental induced effects" between production and households. Therefore, the Leontief and Miyazawa demographic economic model is extended in the RHSA version of SAM-K/LINE® with individual governmental consumption.

Mathematical structure and detailed formation of the model, which includes a further decomposition of the A-, V-, C-, and G-matrices is documented in Madsen, Clausen and Virtanen (2019).

On the basis of the linkages between actors and markets, as depicted by the aforementioned A-, V-, C-, and G-matrices, the sub-models for labour market for HCPs and individual governmental consumption for health care and education can be constructed and examined. Other examples of the formulation of sub-models within LINE® can be found in the studies by Madsen & Zhang (2010) and Zhang (2014), which look at tourism activity and consumption in Denmark.

In addition to the quantity model, the RHSA version of SAM-K/LINE® includes a cost-price model, which is the mirror to the quantity model (circulating in an anti-clockwise direction in the diagram space). The cost-price model accounts for the supply and demand of commodities, labour and income (in current prices) as well as financial balances for households and governmental institutions, implicitly using the savings and tax rates for model closure. For the sake of this paper, the cost-price model is not documented (see Madsen, Clausen and Virtanen (2019) for further reference to the model).

Furthermore, the stock-flow model is a model for the size and demographic structure of the population, taking into consideration factors such as age, education as well as geographical distribution. The stock-flow model includes "educational upgrading", both by age and education, which accounts for the in-ward and out-ward flows from the population, at time primo, which then determines ultimo population. The stock-flow model, which is a supply side model, is embedded in the education sub-model, and links directly to the labour market model, both of which will be presented later in this chapter. Future developments include adding inter-regional migration data, as well as data on births and deaths, into the demographic stock-flow model.

3.1 The Sub-Models for Individual Governmental Consumption

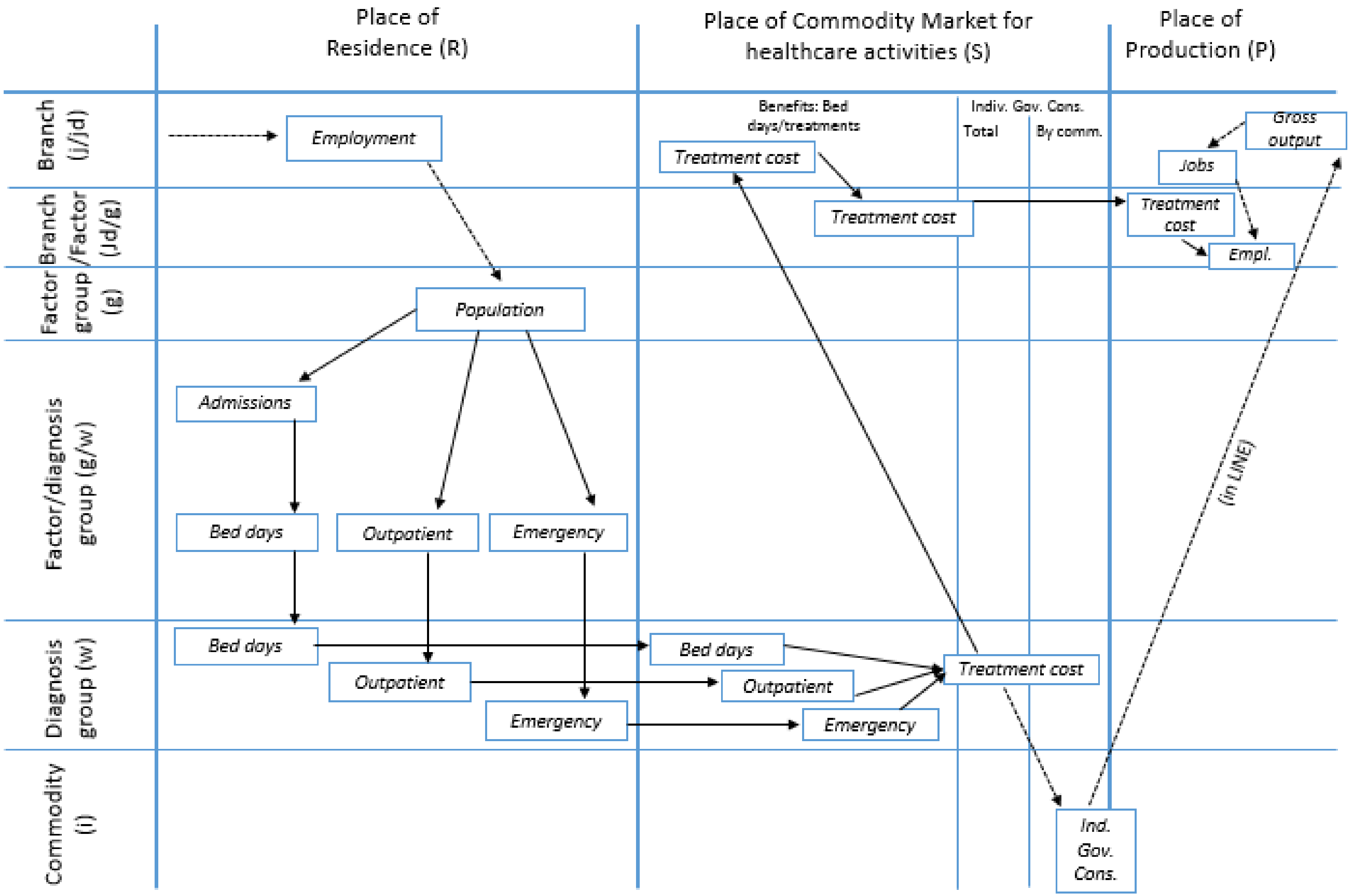
The RHSA version of SAM-K/LINE® includes four sub-models for the demand for individual governmental consumption, including the demand for hospital services, physician services, social and residential care, as well as for education. These sub-models are linked to the extended labour market model, by which the demand for individual governmental consumption feeds to the demand for HCPs and other qualifications.

3.1.1 The sub-model for hospital services

Figure 2 below is a visual representation of the sub-model for individual governmental consumption for hospital services. The case of departure is population size and structure, which enter exogenously into SAM-K/LINE® from the population projection model from Statistics Denmark, while the resulting individual governmental consumption feed back into the main model (depicted in figure 1) to determine production.

In between, an extended sub-model is included which determines the demand for hospital services.

Figure 2: Individual Governmental Consumption for hospital services



SOURCE: SAM-K/LINE®_RHSA18

In the RHSA version of SAM-K/LINE®, hospital services are extended and divided into admission treatments (which extend into bed days), outpatient treatments and emergency treatments, which are distributed by diagnosis group (w) as well as by hospital sub-industry group (j) in which the treatments are performed. In the case of calculating the number of admission treatments, admission rates are multiplied by population, after which admissions are multiplied with the number of bed days/admission. We then get the number of admissions and bed days at the place of residence (B), by population factors (g) and by diagnosis (w). Outpatient treatments and emergency treatments, on the other hand, are obtained through a single-step calculation, by multiplying population with respective treatment rates, also at the place of residence (B), by population factors (g) and by diagnosis group (w). The total number of bed days, ambulatory treatments and emergency room treatments are then calculated by summing up gender, age and education. For the list of hospital diagnoses included in the RHSA, refer to Table A5 in Appendix A.

Next, the number of bed days, emergency room treatments and outpatient treatments are transformed from the place of residence (B) to the place of the commodity market (S), where the healthcare or education institution is placed- still by diagnosis group (w). From here, the number of bed days, outpatient treatments and emergency treatments are transformed into costs for outpatient treatments, emergency treatments and bed days, which are then summed up to total hospital treatment costs.

From total treatment costs at the commodity market, the model splits into two directions. The first is shown by the dotted line going from demand (at the place of commodity market) and through the trade system to production of the aggregated hospital industry and hospital commodity (at the place of production), and further to jobs and employment at the place of production, and by aggregated hospital sector. The second line goes from total cost of hospital treatments, which then divides into detailed hospital departments (by factor group), in order to obtain departmental costs. Finally, cost of treatment is transformed from place of treatment (commodity market/detailed hospital department) to the place of production, and onwards from cost to employment by number of hours (by department and factor group). Thus, employment is modelled in two ways, by number of people and by number of hours. Cost calculations are based on price lists for payments of hospital services, which the municipalities decide in connection with hospitalization and course of treatment. Individual governmental consumption is scaled and converted at the national level, allowing for the demand for hospital services to be aligned and merged with the regional commodity balances in accordance with regional nation accounts and SAM-K.

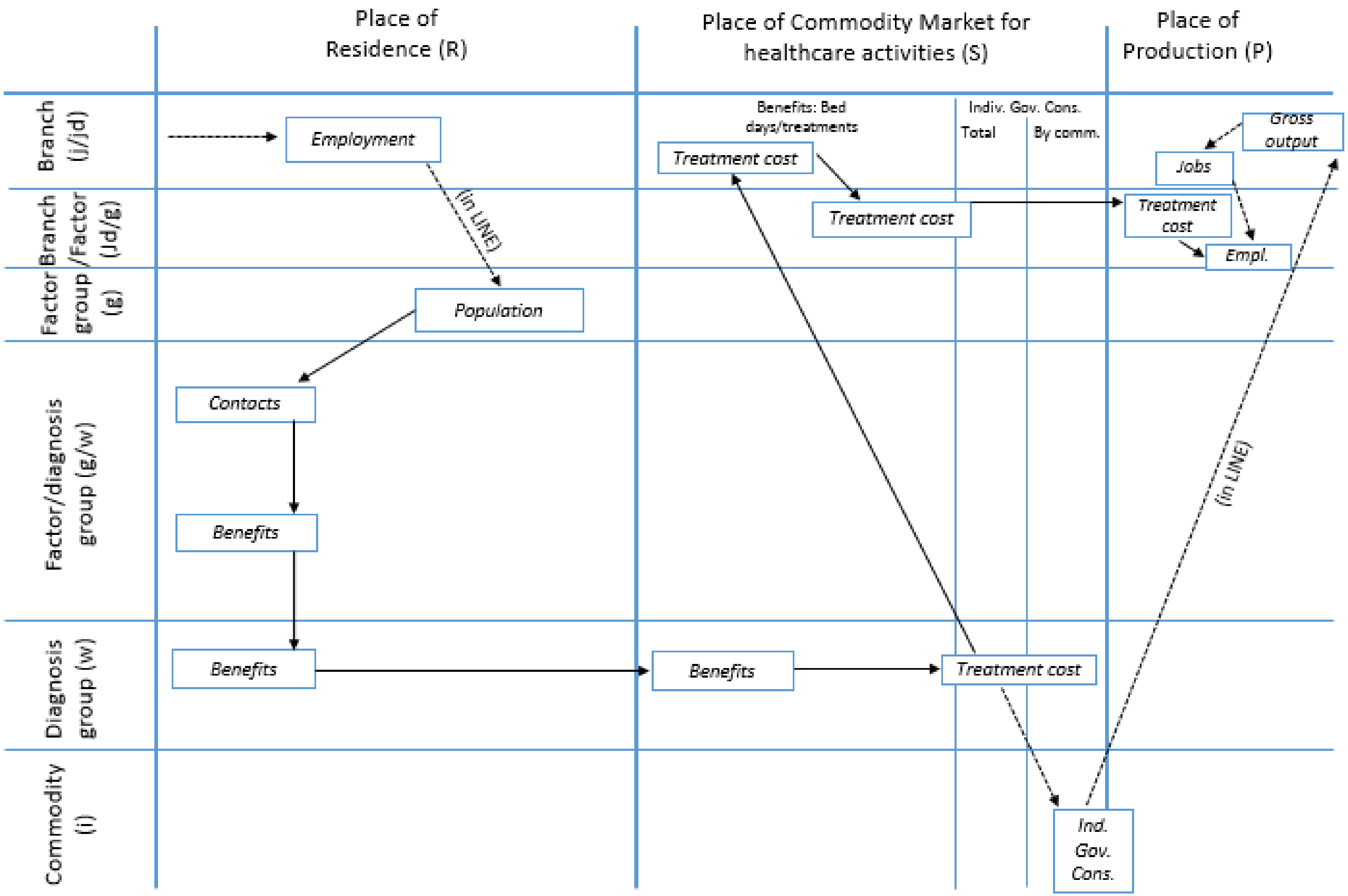
3.1.2 The sub-model for physician services

The sub-model for the individual governmental consumption of physician services largely corresponds to the hospital sub-model outlined above. The sub-model starts with the number of patient contacts, which are calculated on the basis of population characteristics and contact frequency rates, divided by place of residence, gender, age and education of the individual receiving treatment. The contact frequency indicates the number of contacts with the physician, dentist, chiropractor, etc. per person.

Then, on the basis of number of contacts with physician services, the number of benefits per contact can be calculated. Hereafter, the physician benefits by gender, age, education and social status are summed, so that physician benefits by place of residence can be divided by type of practice/physician service. For the list of physician services, refer to Table A6 in Appendix A. Next, physician benefits by type of practice are converted from place of residence to the place of the commodity market (in which the practice is located). This takes into consideration the "shopping" that may exist between two different municipalities, when the place of residence may not be the same as the place of the commodity market.

Hereafter, the number of physician benefits are then converted to costs based on settlement prices as reported to the health insurance institution. Finally, costs are scaled and converted to individual governmental consumption on the national accounting level, allowing for the demand for physician services to be aligned and merged with the regional commodity balances in accordance with regional national accounts (KRNR) and SAM-K. (see figure 3).

Figure 3: Individual Governmental Consumption for physician services



SOURCE: SAM-K/LINE®_RHSA18

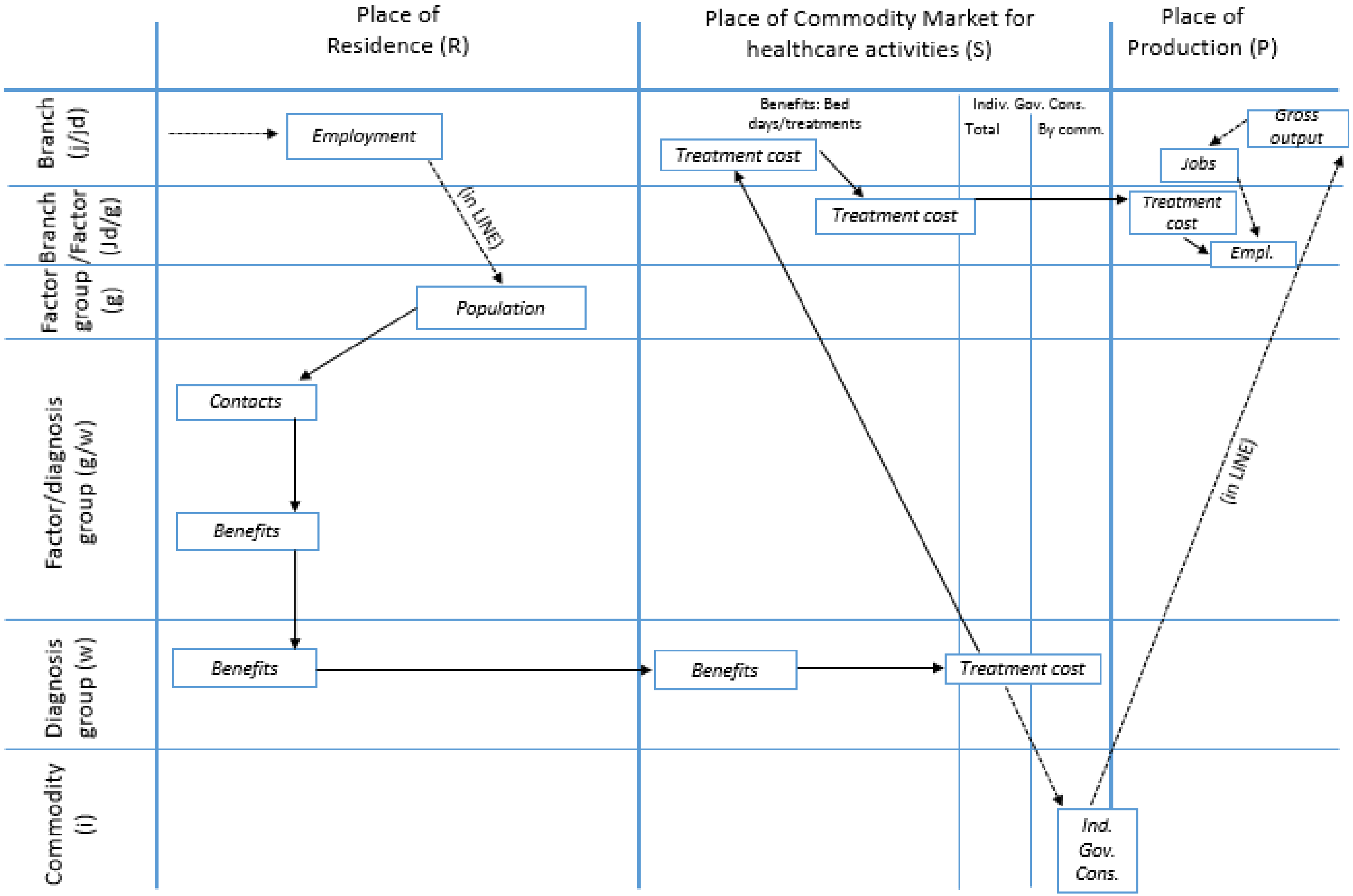
3.1.3 The sub-model for social and residential care services

The sub-model for the individual governmental consumption of care services largely corresponds to the aforementioned models for hospital and physician services. Again, the number of care contacts are determined at the beginning, and are based on population characteristics and contact rates, divided by place of residence, gender, age and education. The contact frequency indicates the number of contacts with care services per person.

Then, on the basis of the number of care services, the number of care benefits per contact can be calculated. Hereafter, the number of care benefits by gender, age, education and social status are summed up, so that care benefits by place of residence can be divided by type of care service. For the aggregation list of care services, refer to Table A7 in Appendix A. Next, care benefits by type of care are converted from the place of residence to the place of commodity market. For care services specifically, the commodity market is often the same as the place of residence, as many care treatments take place at the patient's home, but the model still allows for any "shopping" that may exist two geographically different locations.

Hereafter, the number of care benefits are converted to costs based on settlement prices, which are lastly scaled and converted to individual governmental consumption on the national accounting level, allowing for data on the demand for care services to be recognized in the regional commodity balances in accordance with regional national accounts (KRNR) and SAM-K. (see figure 4)

Figure 4: Individual Governmental Consumption for residential care services

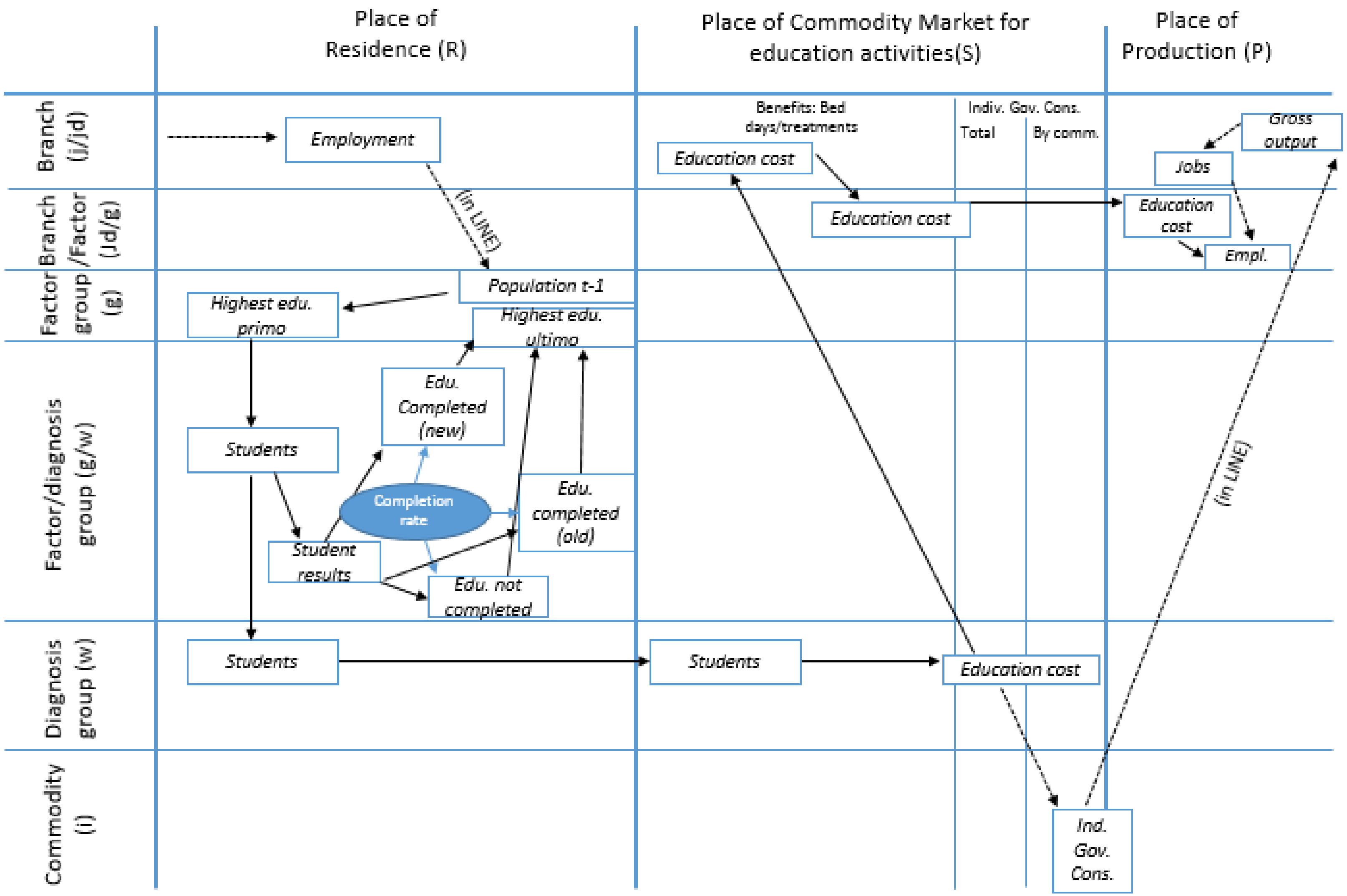


SOURCE: SAM-K/LINE®_RHSA18

3.1.4 The sub-model for education services

Figure 5 below is a diagrammatic representation of the education sub-model, the result of which is the individual governmental consumption for education services, and therefore gross output and employment subject to the demand for education.

Figure 5: Individual governmental consumption of education services



SOURCE: SAM-K/LINE®_RHSA18

As with the three sub-models for health services, the point of departure is the exogenous population: the primo population (by gender, age and education) determines the number of students as primo population multiplied with start-up frequencies (e.g., how many people start a given education) which are a function of admission rates.

The model then calculates the total number of education-seekers, with the upgraded level and field of education, on a given education program (w), with population factors summed away. From here, the education-seekers by type of education are converted from place of residence (R) to the place of the commodity market (S), namely where the educational institution is located.

As with the health-related sub-models, costs for individual public consumption of education services are then calculated on the basis of the price settlement with the educational institutions. Hereafter, costs are converted to individual governmental consumption at the national accounting level, allowing for data on the demand for education services to be aligned and merged with the regional commodity balances in accordance with regional national accounts and SAM-K.

The model uses 4 different education dimensions: highest completed education (HUD), highest completed education ultimo (HUDU), ongoing education primo (IUDP) and ongoing education ultimo (IUDU). The education aggregations can be found in Appendix A under Table A3.

The sub-model for education services is integrated in the population stock-flow model, which is described in the following section.

4 The Population Stock-Flow Module

In the quantity model, as presented in Figure 1, the population was included exogenously as given and was not updated as a result of new educations. However, in order to get a more accurate projection of future labour supply by education, an education-graduation model is included to account for changes in the education structure of the population, therefore endogenizing the population. Within the education sub-model is in addition developed a pre-model, which models the ultimo population by education subject to the primo population by education, minus those who leave the education during the given year. The mathematical structure, as outlined in the technical documentation of the model (Madsen, Clausen and Virtanen, 2019) is the following:

$$\Delta \boldsymbol{u}_{t,t-1} = \boldsymbol{eduNEW}_{t,t-1} - \boldsymbol{eduOLD}_{t,t-1}$$

(3.1a)

$$= \boldsymbol{IG}'\#'\boldsymbol{PEQ}^{R}_{e,t,t-1}\#\boldsymbol{UEQ}^{R}_{e,t-1}{}'\#'\boldsymbol{u}_{t-1} - \boldsymbol{IE}'\#'\boldsymbol{PEQ}^{R}_{e.t,t-1}\#\boldsymbol{UEQ}^{R}_{e.t-1}{}'\#'\boldsymbol{u}_{t-1} \qquad \textbf{(3.1b)}$$

Where:

$\boldsymbol{eduNEW}_{t,t-1}, \boldsymbol{eduOLD}_{t,t-1}$: newly completed highest level of education ($\boldsymbol{eduNEW}$) and former highest level of education ($\boldsymbol{eduOLD}$) from year t-1 to year t, by population factors (g) and at the place of residence.

$\boldsymbol{UEQ}^{R}_{e,t-1}$: the share (Q) of population, who were under education (E), by field of ongoing education (e), population factors (g), and at the place of residence (R).

$\boldsymbol{PEQ}^{R}_{e.t,t-1}$: the share (Q) of population, who completed the education (P), by field of ongoing education (e), population factors, and at the place of residence.

$\boldsymbol{IG}, \boldsymbol{IE}$**:** Aggregation by field of primo education (g) and by field of ongoing education (e)

#: element to element multiplication

The second line of the equation reflects an expansion by which the number of graduates (u) is calculated in a two-step form. First, the primo population determines the number of students as primo population multiplied with education start-up frequencies ($\boldsymbol{UEQ}^{R}_{e,t-1}$). In the second step the share of students, who graduates ($\boldsymbol{PEQ}^{R}_{e,t,t-1}$), is determined. By aggregating the primo education, the number of graduates is determined.

When students graduate and become member of a new education group ($\boldsymbol{eduNEW}_{t,t-1}$), they also leave their former education group ($\boldsymbol{eduOLD}_{t,t-1}$).

The table 2 is a graphical example of the education stock-flow module for midwives in Denmark between the years 2016 and 2025. It shows the number of newly educated midwives in a given year, which are added to the exogenous primo population at the beginning of the year, and the number of people who obtain another education during the year, which are then subtracted from the primo population. The resulting endogenous population accounts for the inward and outward flows from a stock of people with a given education. Further ambitions of the RHSA Model of SAM-K/LINE®, include additional data on in- and out-migration (both to/from abroad and inter-regional migration) as well as data on births and deaths.

Table 2: Education stock-flow module for midwives in Denmark, 2016-2025

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Midwife population primo	2.866	2.866	2.949	3.036	3.132	3.236	3.341	3.450	3.554	3.656
New midwife graduates	128	128	139	153	165	170	171	171	172	172
Former midwives	31	31	33	34	35	37	39	39	41	43
Net change	97	97	106	119	130	133	133	132	131	130
Midwife population ultimo	2.963	2.963	3.056	3.155	3.262	3.370	3.474	3.582	3.685	3.786

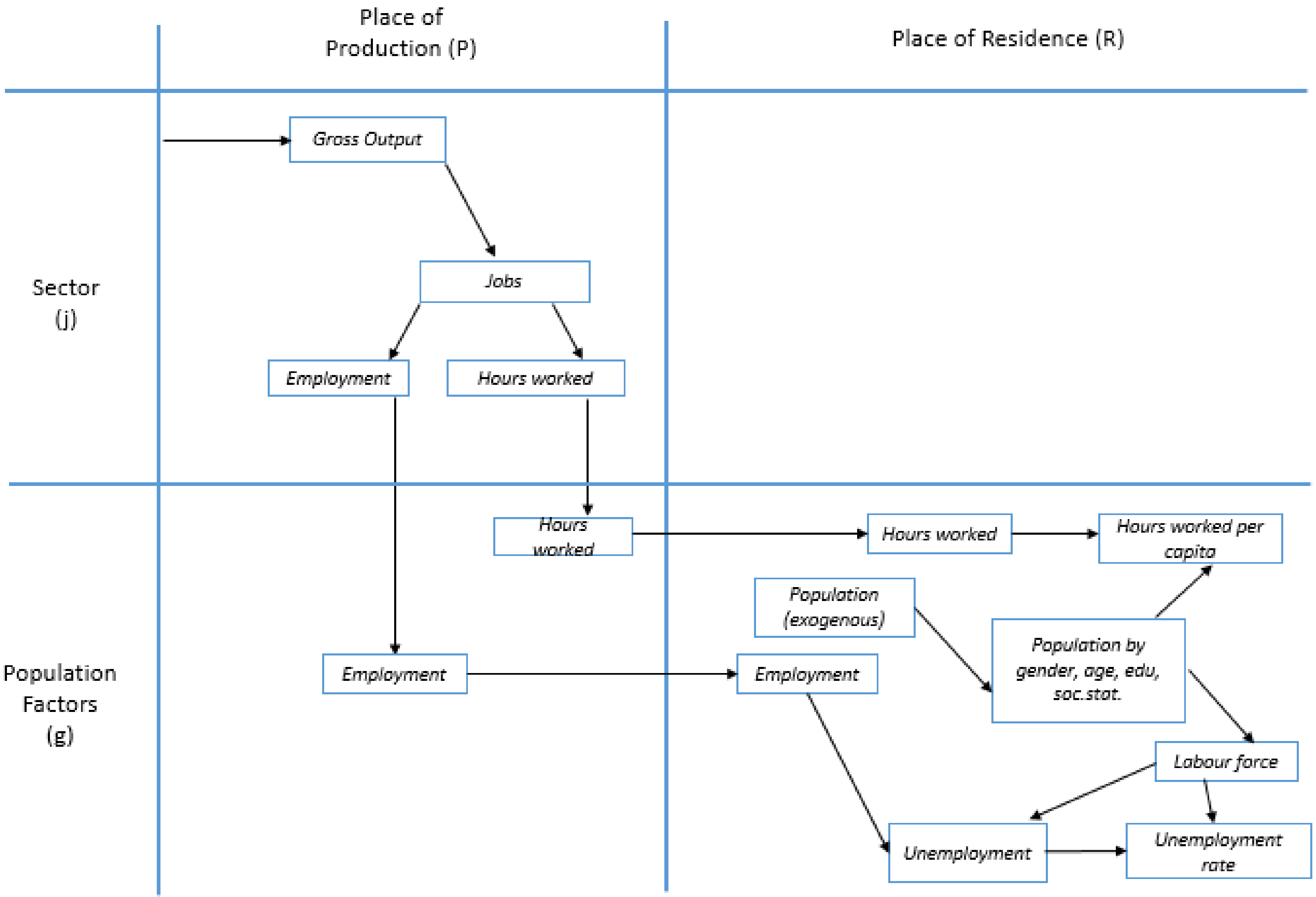
SOURCE: SAM-K/LINE®_RHSA18

The stock-flow education module is a bottom-up component to forecasting population by education. Due to political reasons as well as user interest, the resulting endogenous population is scaled to a top-down component, which is the national population forecast, by gender and age, as given by Statistics Denmark. However, the educational distribution is taken from the resulting population from the education stock-flow module. This resembles a typical regional national economic model approach, in which a bottom-up approach is met with a national top-down approach (Nijkamp, Rietveld, and Snickars, 1987).

5 The Module for Regional Labour Market

The figure 6 depicts the labour market module in the RHSA version of SAM-K/LINE®, which begins, as in the general version of LINE®, from gross output at the place of production by producing sector. The demand for governmental services (healthcare and education), as demonstrated earlier in this chapter, partly determine gross output, or production, and therefore jobs and employment. As depicted by the sub-models for hospital services, physician services and social/residential care services, the causality between individual governmental consumption demand and production are treated in two ways: at the aggregated level (one industry, one commodity) and at the disaggregated level (detailed groups of treatment/education commodities and by detailed sub-industries) (see section 3.1)

Figure 6: Labour Market Module



SOURCE: SAM-K/LINE®_RHSA18

The demand for HCP labour in LINE® is partly determined by the demand for governmental services and otherwise by production and the employment structure of the healthcare producing industries. As described earlier, the link between individual governmental consumption and production of healthcare and education services is determined at the aggregated and at the disaggregated levels, but within the labour market module, resulting number of jobs at the disaggregated level are scaled according to the number of jobs in the aggregated industries so that the total sums are equal.

Furthermore, employment is modelled both by number of people, as well as by number of hours. The number of hours is further broken down to number of hours worked in main employment, secondary employment as well as foreign employment (number of hours from employees with residential address outside Denmark). The motivation for including employment in number of hours in addition to employment by number of people is that part-time work and secondary employment is rather common in the healthcare industries in Denmark. In some cases, doctors and nurses may be employed at two different departments, but it would only show in data under job hours worked. Further, employment by number of hours allows us to identify potentially unused labour; for example, in the case of a retired person who works part-time, his or her main activity may still be "retired", but he or she is still engaged in a secondary activity with part-time hours. This is also relevant in the case of employed specialised doctors in Denmark, of which 65 percent were above the age of 51 and 16 percent above the age of 66[3] in 2016.

On the other side, the aforementioned population stock-flow module for education also interacts with the labour market module (at the place of residence by population factors age, gender, education and socioeconomic status), as labour supply now includes an updated level of education.

The crossing of the two sides of the labour market module, namely labour supply and labour demand, results in unemployment (determined at the place of residence by population factors, as shown in Figure 6), which unveils any potential imbalances in the labour market for HCPs.

[3] In Denmark retirement age is 65 until 2022. After 2022 the retirement age will be 67. The changes in retirement age is incorporated in the labour market module of SAM-K/LINE®

6 Scenario Analysis

CRT, together with The Capital Region of Denmark, developed scenario experiments in the SAM-K/LINE®_RHSA18. The scenario experiments are designed to test and analyse any foreseeable policy actions and initiatives in the Danish healthcare sector. For one, the scenario tool creates the possibility to find empirically and politically viable and relevant results in order to meet a balanced HCP labour market in future. In order to model scenarios with the RHSA model, it requires an explicit alteration to one or more of the exogenous parameters in the model. In some cases, a scenario may require new data to be read in. Currently, there are three scenarios developed, or under development with the RHSA, such as:

1. Healthy ageing of the elderly population.
    a. With consideration for the future demand and supply of health personnel, demographic trends matter. How does the witnessed demographic phenomenon of healthy ageing affect future labour demand for health personnel?
    b. With healthy ageing, we can expect older employees to prolong retirement and remain economically active for a longer period. This has positive effects on labour supply.
        i. For example, approximately 65% of all special doctors are above the age of 51 and 16% above the age of 66, which account for a large share of total labour supply of special doctors.
    c. With other things being equal, healthy ageing can be expected to result in a decrease in individual governmental consumption, which will lead to less demand for health care professionals and potentially higher unemployment.
2. Changing educational capacity
    a. What effects does a change in the educational capacity of a certain field of education have on future labour market conditions?
        i. Example: midwife education, increase of 30 additional places in 2017.
3. Change in illness/treatment patterns.
    a. How does an increase in the prevalence of a certain type of treatment or illness affect the demand for certain health care professions? How does it affect productivity and economic activity?
        i. For example, Denmark statistics expects a 22% increase in the number of births between 2016 and 2030? What effects does this have on the demand for midwives, paediatric specialists, etc.? What are the effects of more mothers being temporarily out of the workforce?

7 Appendices

A: Aggregations for SAM-K/LINE®_RHSA18

Table A1a: Age, "ALDER" (3 age groups used in A, B, AB sections of SAM-K, LINE1)

ALDER	Three age groups: young, middle, old.
ALDER0029	Ages 0-29 (also includes -1, 112-129*)
ALDER3059	Ages 30-59 (also includes 130-159*)
ALDER6000	Ages 60-100 (also includes 160-high, others*)

*According to Denmark Statistics, the oldest person in Denmark is currently 110 years old.

Table A1b: Age, "ALDERDE" (One-year age groups from 15-39, used for education variables in BD Section of SAM-K, LINE1)

ALDERDE	Only ages 15-39
ALDERDE00	
ALDERDE15	Age 15
ALDERDE16	Age 16
ALDERDE17	Age 17
..	Age 18, 19, 20, 21, and so forth.
ALDERDE39	Age 39

Table A1c: Age, "ALDERDET (One-year age groups from 0-129, used in BD Section of SAM-K, LINE1)

ALDERDET	1-year age groups
ALDERDET0	Age 0
ALDERDET1	Age 1
ALDERDET2	Age 2
…	Age 3-127
ALDERDET128	*
ALDERDET129	*

*According to Denmark Statistics, the oldest person in Denmark is currently 110 years old. Years 110+ for data discrepancies, by which a 29-year old may be reported as "129".

Table A2a: Sector, ERD at the M (model-level)

Sectors	ERD code	Industry code
A Agriculture, forestry and fishing	ER2M01	A
B Mining and quarrying	ER2M02	B
C1 Manufacturing & Industry (incl. food production, tobacco, etc.)	ER2M03	C1
C2 Medicinal Industry	ER2M04	C2
C3 Other electronic equipment	ER2M05	C3
C4 Medical Instruments	ER2M06	C4
D Energy supply	ER2M07	D
E Water supply and waste collection	ER2M07	E
F Construction	ER2M08	F
G1 Commerce	ER2M09	G
G2 Commerce: wholesale trade	ER2M10	G
G3 Commerce: Retail	ER2M11	G
H Transportation	ER2M12	H
I Hotels and restaurants	ER2M13	I
J Information and communication, Finance and Insurance, Real estate and commercial leasing, Knowledge services, Travel agents, Cleaning	ER2M14	J, K, LA, LB, M, N
O Public administration, defence, emergency services and police	ER2M15	O
P Education		P
850010 Elementary Schools	ER2M16	850010
850020 High schools and vocational schools	ER2M17	850020
850030 Institutions of higher education	ER2M18	850030
850042 Adult education etc., non-commercial & commercial	ER2M19	850042
Q Health and social services		Q
Q1 Hospitals	ER2M20	860010
Q2 Doctors (physicians), dentists, etc.	ER2M21	860020
Q3 Care homes etc.	ER2M22	870000
Q4 Day care centres and day centres etc.	ER2M23	880000
R Culture and leisure (Theatre, Libraries, Museums, Gambling, Sports, Amusement parks, etc.)	ER2M24	R
S Other services (hairdressers, reparation of household equipment, etc.)	ER2M25	S

Table A2b: Sector, ERD1, SAM-K

Sectors	ERD code	Industry code
A Agriculture, forestry and fishing	ERD101	A
B Mining and quarrying	ERD102	B
C1 Manufacturing & Industry (incl. food production, tobacco, etc.)	ERD103	C1
C2 Medicinal Industry	ERD104	C2
C3 Other electronic equipment	ERD105	C3
C4 Medical Instruments	ERD106	C4
D Energy supply	ERD107	D
E Water supply and waste collection	ERD107	E
F Construction	ERD108	F
G1 Commerce	ERD109	G
G2 Commerce: wholesale trade	ERD110	G
G3 Commerce: Retail	ERD111	G
H Transportation	ERD112	H
I Hotels and restaurants	ERD113	I
J Information and communication, Finance and Insurance, Real estate and commercial leasing, Knowledge services, Travel agents, Cleaning	ERD114	J, K, LA, LB, M, N
O Public administration, defence, emergency services and police	ERD115	O
P Education		P
850010 Elementary Schools	ERD116	850010
850020 High schools and vocational schools	ERD117	850020
850030 Institutions of higher education	ERD118	850030
850042 Adult education etc., non-commercial & commercial	ERD119	850042,
Q Health and social services		Q
Q1 Hospitals		Q
Other hospital functions (not sub-sectors 1-22 below)	ERD120	861000
Hospital sub-sector 1: Geriatrics	ERD121	
Hospital sub-sector 2: Internal Medicine	ERD122	
Hospital sub-sector 3: Cardiology	ERD123	
Hospital sub-sector 4: Medical lung diseases	ERD124	
Hospital sub-sector 5: Acute Medicine	ERD135	
Hospital sub-sector 6: Dermato-Venereology	ERD126	
Hospital sub-sector 7: Neurology	ERD127	
Hospital sub-sector 8: Oncology	ERD128	
Hospital sub-sector 9: Surgery	ERD129	
Hospital sub-sector 10: Plastic Surgery	ERD130	
Hospital sub-sector 11: Gynaecology and obstetrics	ERD131	
Hospital sub-sector 12: Orthopaedic Surgery	ERD132	

Hospital sub-sector 13: Sense Organs	ERD133	
Hospital sub-sector 14: Psychiatry	ERD134	
Hospital sub-sector 15: Laboratory Practice	ERD135	
Hospital sub-sector 16: Pathological Anatomy	ERD136	
Hospital sub-sector 17: Imaging	ERD137	
Hospital sub-sector 18: Paediatrics	ERD138	
Hospital sub-sector 19: Anaesthesiology	ERD139	
Hospital sub-sector 20: Social and occupational Medicine	ERD140	
Hospital sub-sector 21: General Medicine	ERD141	
Hospital sub-sector 22: Other specialties	ERD142	
Q2 General Practice, Dentists, etc.		Q
General Practice	ERD143	862100
Specialist Practice	ERD144	862200
Dental Practice	ERD145	863000
Home Nursing, healthcare	ERD146	869010
Physiotherapy, Occupational therapy	ERD147	869020
Psychological Counselling	ERD148	869030
Chiropractor	ERD149	869040
General health care - others	ERD150	869090
Q3 Care homes, etc.		Q
Nursing homes	ERD151	871010, 871020
Care Centres for adults	ERD152	872010, 872020, 873010, 873020
Care Centres for young	ERD153	879010, 879020, 879090
Q4 Day care centres and day centres etc.		Q
Home help/care	ERD154	881010, 881020, 881030
Day care centres for children and young	ERD155	889110-889160, 889910, 889920, 889990
R Culture and leisure (Theatre, Libraries, Museums, Gambling, Sports, Amusement parks, etc.)	ERD156	R
S Other services (hairdressers, reparation of house-hold equipment, etc.)	ERD157	S

Table A3: Highest education (HUD) by field of education and ongoing education (IUD) by field of education. *

HUD code	Field of Education
HUD01	Unskilled/undisclosed (0-9th years of Primary and Secondary School)
HUD02	Students, hf, hhx, htx (10-12th years of High School)
HUD03	Social and health care worker
HUD04	Social and health care assistant
HUD05	Doctor secretary
HUD06	EFU & KVU – Other health-related.
HUD07	EFU & KVU – Not health-related
HUD08	Bio annalist, Prof. Bach.
HUD09	Nurse, Prof. Bach.
HUD10	Radiographer, Prof. Bach.
HUD11	Occupational Therapist, Prof. Bach.
HUD12	Physiotherapist, Prof. Bach.
HUD13	Midwife, Prof. Bach.
HUD14	MVU – Other health-related
HUD15	MVU – Not health-related
HUD16	Medicine, BM.
HUD17	Psychology, BM.
HUD18	Pharmacist, BM.
HUD19	Bachelor – Other health-related
HUD20	Bachelor – Not health-related
HUD21	Medicine, MMed.
HUD22	Psychology, MMed.
HUD23	Pharmacist, MMed.
HUD24	LVU – Other health-related
HUD25	LVU – Not health-related
HUD26	Doctor Speciality: Geriatrics
HUD27	Doctor Speciality: Internal Medicine
HUD28	Doctor Speciality: Cardiology
HUD29	Doctor Speciality: Medical lung diseases
HUD30	Doctor Speciality: Acute Medicine
HUD31	Doctor Speciality: Dermatologist-Venereology
HUD32	Doctor Speciality: Neurology
HUD33	Doctor Speciality: Oncology
HUD34	Doctor Speciality: Surgery
HUD35	Doctor Speciality: Plastic Surgery
HUD36	Doctor Speciality: Gynaecology and obstetrics
HUD37	Doctor Speciality: Orthopaedic Surgery
HUD38	Doctor Speciality: Sense Organs
HUD39	Doctor Speciality: Psychiatry

HUD40	Doctor Speciality: Laboratory Practice
HUD41	Doctor Speciality: Pathological Anatomy
HUD42	Doctor Speciality: Imaging
HUD43	Doctor Speciality: Paediatrics
HUD44	Doctor Speciality: Anaesthesiology
HUD45	Doctor Speciality: Social and occupational Medicine
HUD46	Doctor Speciality: General Medicine
HUD47	Doctor Speciality: Other

*IUD TAKES THE SAME FORM AS HUD, APART FROM AN ADDITIONAL GROUP (IUD00) WHICH INCLUDES THOSE THAT ARE CURRENTLY NOT UNDERGOING EDUCATION.

Table A4: DIM2, Social Status

DIM2 Code	Social Status
DIM201	Employed
DIM202	Unemployed
DIM203	Cash Benefits, Introduction Benefits
DIM204	Undergoing education
DIM205	Temporarily out of the workforce
DIM206	Pension
DIM207	Early retirement (Efterløn) + “others”
DIM208	Children and young

Table A5: Diagnostic Groups: Hospitals

Diagnosis code	Group
DIAGH01	Infectious diseases
DIAGH02	Lung diseases
DIAGH03	Diseases of the nervous system
DIAGH04	Diseases of the heart and large vessels
DIAGH05	Diseases of arteries, veins and lymphatic system
DIAGH06	Varicose veins
DIAGH07	Blood disorders
DIAGH08	Gastrointestinal diseases
DIAGH09	Urinary tract infections
DIAGH10	Diseases of the musculoskeletal system
DIAGH11	Gynaecological disorders
DIAGH12	Diseases of pregnancy and childbirth
DIAGH13	Skin and venereal diseases
DIAGH14	Eye disorders
DIAGH15	Ear, nose and throat diseases
DIAGH16	Endocrine, metabolic and chromosomal diseases
DIAGH17	Mental illness

DIAGH18	Diseases of the breast
DIAGH19	Sterilisations
DIAGH20	Concussion
DIAGH21	Poisoning
DIAGH22	Live-born children
DIAGH23	Other diseases
DIAGH99	Undisclosed
DIAGH total	All diseases

Table A6: Physician Practice Groups

Practice code	Group
DIAP01	General doctor
DIAP02	Duty doctor
DIAP03	Ophthalmologist
DIAP04	Ear nose and throat doctor
DIAP05	Other specialist
DIAP06	Dentist
DIAP07	Physiotherapy clinic, physiotherapist, chiropractor
DIAP08	Podiatrist
DIAP09	Psychologists
DIAP10	Other + Unknown
DIAGP total	Practice total

Table A7: Nursing and Residential Care Activities

Activity code	Activity
DIAC01	Activity
DIAC02	Nutrition
DIAC03	Skin and mucous membranes
DIAC04	Communications
DIAC05	Psychosocial conditions
DIAC06	Respiration and circulation
DIAC07	Sexuality
DIAC08	Pain and sensory impressions
DIAC09	Sleep and rest
DIAC10	Knowledge and development
DIAC11	Excretion and waste products
DIAC12	Observation of efficacy and possible effect of treatment
DIAC13	Acute
DIAC99	Other
DIAGC total	All diseases

B: Equations for the Regional Labour Market Module in RHSA

In this appendix, the labour market module in LINE®, including the equations for

- labour demand going from the number of jobs and working hours distributed by sector and the place of production (gross output) to the number of employed and working hours and to the factor group (gender, age, education and socio-economic status) and to the place of residence and
- labour supply from the population from group (gender, age) to sub-groups (gender, age, education and socio-economic status) at place of residence and through activity rates to labour supply

are presented.

The equations in the labour market module is a subset of the equations in LINE®-model presented in "circle order" starting in the upper left corner of the diagram of the labour market module and following the model circle in the lower right corner.

The equations are presented in two forms, shown in the left and the right columns below:

- "Conventional" equation form, where indices are referred to as upper or lower indices and using conventional array operators such as multiplication, summation etc.
- "Tensor form" presented in the right column, where the variables are in "computer program language form", where the variable names include the indices (geographical and Social Accounting Matrix specification) in the variable name.

This appendix describes variable names and mathematical notation, the system behind variables names (with explanation of letters in variables names) and the different forms of mathematical operations in detail.

The list of key labour market variables:

Jobs:

Number of jobs (qn) by sector (j) and place of production (p)

$qn_j^P = QNXQ_j^P x_j^{P,f}$ ……………………….or……….. $qnpj = QNXPJQ\#xpjf$ ……………………………………………………………………(I)

Employment (hours worked):

Employment (q) in number of hours worked (t) by sector (j) and place of production (p)

$qt_j^P = QNTQ_j^P qn_j^P$ ……………………….or……….. $qtpj =$ $QNTPJQ\#qnpj$ ……………………………………………………………………(II)

Employment (q) in number of hours worked (t) by gender, age, education and socio-economic status (g) and place of production (p)

$qt_g^P = \sum_j QTQ_{j,g}^P qt_j^P$ ……………………….or……….. $qtpg =$ $QTPJGQ'\#'qtpj$ ………………………………………………………………(III)

Employment (q) in number of hours worked (t) by gender, age, education and socio-economic status (g) and place of residence (r)

$qt_g^R = \sum_P QTQ_g^{P,R} qt_g^P$ ……………………….or……….. $qtrg =$ $QTPRGQ'\#'qtpg$ ……………………………………………………………(IV)

Employment (persons):

Employment (q) in persons (u) by branch (j) and place of production (p)

$qu_j^P = QNUQ_j^P qn_j^P$ ………………………….or……….. $qupj =$ $QNUPJQ"\#"qnpj$ …………………………………………………………………(V)

Employment (q) in persons (u) by gender, age, education and socio-economic status (g) and place of production (p)

$qu_g^P = \sum_j QUQ_{j,g}^P qu_j^P$ …………………….or………… $qupg =$ $QUPJGQ'\#'qupj$ ……………………………………………………………(VI)

Employment (q) in persons (u) by gender, age, education and socio-economic status (g) and place of residence (r)

$qu_g^R = \sum_P QUQ_g^{P,R} qu_g^P$.......................or.............$qurg =$
$QUPRGQ'\#'qupg$...(VII)

Population, labour force and unemployment (persons):

Population (u) by gender, age, education and socio-economic status (g) and place of residence (r)

$u_g^R = UAGQ_{a,g}^R u_a^R$.................or...........$urg =$
$URAGQ"\#"ura$..(VIII)

Number (u) in labour force (s) by gender, age, education and socio-economic status (g) and place of residence (r)

$us_g^R = USQ_g^R u_g^R$................................or...........$usrg =$
$USRGQ"\#"urg$...(IX)

Participation or activity rates:

Number (u) unemployed (l) by gender, age, education and socio-economic status (g) and place of residence (r)

$ul_g^R = us_g^R - qu_g^R$.............................or...........$ulrg = usrg -$
$qurg$...(X)

Number (u) of unemployed (l) rate (q) by gender, age, education and socio-economic status(g) and place of residence (r)

$ULQ_g^R = ul_g^R / us_g^R$..........................or...........$ULRGQ = ulrg/$
$usrg$...(XI)

Employment (q) in number of hours (t) per capita (u) by gender, age, education and socio-economic status (g) and place of residence (r)

$QTUQ_g^R = qt_g^R / u_g^R$..........................or...........$QTURGQ = qtrg/$
urg..(XII)

C: Equations for the Individual Governmental Consumption Sub-Models in RHSA

This section provides mathematical explanation of the RHSA sub-models, described in the section 3.1.

As mentioned above, these sub-models are extended sub-circles in individual governmental consumption in LINE®. Equations follow the sub-circle

- From the place of residence of the population, who consume the healthcare services to the place of commodity market (or place of the healthcare institutions)
- From the population by group (gender, age and education) to services by product type (treatments by diagnosis, type of benefit or education activity)
- From the treatment measured in quantities to monetary units, either "bottom-up" in current prices using administrative prices or "top down" in fixed prices following national account pricing.

The equations in the RHSA sub-model is presented in the "circle order" starting in the upper left corner of the diagrams of the 4 four sub-models (at the place of residence R and by the factor g) and following the model circle to the place of commodity market and by type of treatment or commodities as illustrated in the graphical presentation of the sub-model in the sections 3.1.1 to 3.1.4.

The equations are presented in two forms:

"Conventional equation form" presented in the left column below, where indices are referred to as upper or lower indices and using conventional array operators such as multiplication, summation etc.

"Tensor form" presented in the right column, where the variables are in "computer program language form", where the variable names include the indices (geographical and Social Accounting Matrix specification) in the variable name.

Governmental consumption:

Hospitalization:

Number (u) of hospital (h) admissions (i) by gender, age and education (g), main diagnosis (w) and place of residence (R)

$uhi^R_{g,w} = UHIQ^R_{g,w}u^R_g$..........................or...........$uhirgw = UHIRGWQ\#urg$ ....(I.a)

Number (u) of hospital (h) bed days (b) by gender, age and education (g), main diagnosis (w) and place of residence (R)

$uhb^R_{g,w} = UHBQ^R_{g,w}uhi^B_{g,w}$..................or..............$uhbrgw = UHBRGWQ\#uhirgw$...(I.b)

Number (u) of hospital (h) bed days (b) by main diagnosis (w) and place of residence (R)

$uhb^R_w = \sum_g uhs^R_{g,w}$..........................or..............$uhbrw = IG'\#'uhbrgw$...(I.c)

Number (u) of hospital (h) bed days (b) by main diagnosis (w), by department and type of hospital (o) and place of residence (R)

$uhb^R_{w,o} = UHSOQ^R_{w,o}uhs^R_w$...............or..............$uhbrwo = UHBRWOQ"\#"uhbrw$...(I.d)

Number (u) of hospital (h) bed days (b) by main diagnosis (w), by department and type of hospital (o) and place of commodity market (s)

$uhb^S_{w,o} = \sum_r UHBQ^{R,S}_{w,o}uhb^R_{w,o}$.......or..............$uhbswo = UHBRSWOQ'\#'uhbrw$o..(I.e)

Cost (cor) of hospital (h) bed day (b) by main diagnosis (w), by department and type of hospital (o) and place of commodity market (s)

$corhb^S_{w,o} = CORHSQ^S_w uhb^S_{w,o}$...............or.........$corhbswo = CORHBSWOQ'\#'uhbswo$...................................(I.f)

Out-patient treatments:

Number (u) of hospital (h) out-patient treatments (a) by gender, age and education (g), main diagnosis (w) and place of residence (R)

$uha^R_{g,w} = UHAQ^R_{g,w}u^R_g$..........................or...........$uhargw = UHARGWQ\#urg$ ....(II.a)

Number (u) of hospital (h) out-patient treatments (a) main diagnosis (w) and place of residence (R)

$uha_{w}^{R} = \sum_{g} uha_{g,w}^{R}$.........................or..............$uharw =$ $UHARGWQ'\#'uhargw$..(II.c)

Number (u) of hospital (h) out-patient treatments (a) by main diagnosis (w), by department and type of hospital (o) and place of residence (R)

$uha_{w,o}^{R} = UHAOQ_{w,o}^{R} uha_{w}^{R}$..........or..............$uharwo =$ $UHARWOQ"\#"uharw$..(II.d)

Number (u) of hospital (h) out-patient treatments (a) by main diagnosis (w), by type of hospital (o) and place of commodity market (s)

$uha_{w,o}^{S} = \sum_{r} UHAQ_{w,o}^{R,S} uha_{w,o}^{R}$.......or...............$uhaswo =$ $UHARSWOQ'\#'uharw$o..(II.e)

Cost (cor) of hospital (h) out-patient treatments (a) by main diagnosis (w), by department and type of hospital (o) and place of commodity market (s)

$corha_{w,o}^{S} = CORHAQ_{w}^{S} uha_{w,o}^{S}$...............or.........$corhaswo =$ $CORHASWOQ'\#'uhaswo$.................................(II.f)

Emergency room treatments:

Number (u) of hospital (h) emergency room treatments (e) by gender, age and education (g), main diagnosis (w) and place of residence (R)

$uhe_{g,w}^{R} = UHEQ_{g,w}^{R} u_{g}^{R}$..........................or...........$uhergw = UHERGWQ\#urg$ ....(III.a)

Number (u) of hospital (h) emergency room treatments (e) by gender, age and education (g), main diagnosis (w) and place of residence (R)

$uhe_{w}^{R} = \sum_{g} uhe_{g,w}^{R}$.........................or..............$uherw =$ $UHERGWQ'\#'uhergw$..(III.c)

Number (u) of hospital (h) emergency room treatments (e) by main diagnosis (w), by department and type of hospital (o) and place of residence (R)

$uhe_{w,o}^{R} = UHEOQ_{w,o}^{R} uhe_{w}^{R}$..........or..............$uherwo =$ $UHERWOQ"\#"uherw$...(III.d)

Number (u) of hospital (h) emergency room treatments (e) by main diagnosis (w), by department and type of hospital (o) and place of commodity market (s)

$uhe_{w,o}^{S} = \sum_r UHEQ_{w,o}^{R,S} uhe_{w,o}^{R}$.......or...............$uheswo =$
$UHERSWOQ'\#'uherw$o...(III.e)

Cost (cor) of hospital (h) emergency room treatments (e) by main diagnosis (w), by department and type of hospital (o) and place of commodity market (s)

$corhe_{w,o}^{S} = CORHEQ_{w}^{S} uhe_{w,o}^{S}$...............or.........$corheswo =$
$CORHESWOQ\#uheswo$...................................(III.f)

Hospital treatment – total:

Cost (cor) of hospital (h) by department and type of hospital (o) and by place of commodity market (s)

$corh_{o}^{S} = \sum_w corhb_{w,o}^{S} + \sum_w corha_{w,o}^{S} + \sum_w corhe_{w,o}^{S}$............or

$corhso = i\_w'\#'corhbswo + i\_w'\#'corhaswo +$
$i\_w'\#'corheswo$...(I-III.g)

Governmental consumption (cor) of hospitalization(h) by detailed sector (jd) and place of commodity market (s)

$corh_{jd,j=hosp}^{S} = \sum_o CORHQ_{o,jd}^{S} corh_{o}^{S}$............or........$corhsjd =$
$CORHSOJDQ'\#'corhso$..........................(I-III.h)

Governmental consumption (cor) of hospitalization(h) by commodities (i) and place of commodity market (s)

$corh_{i,i=hosp.com}^{S,f} = \sum_o CORHFQ_{o,i}^{S} corh_{o}^{S}$.........or........$corhsif =$
$CORHSOIFQ'\#'corhso$..........................(I-III.i)

Physicians:

Persons (u) in contacts (c) with physician (p) by gender, age and education (g), type of benefits (w) and place of residence(r)

$upc_{g,w}^{R} = UPCQ_{g,w}^{R} u_{g}^{R}$.........................or............$upcrgw = UPRGWQ\#urg$
....(IV.a)

Number (u) of physician benefits (p), by gender, age and education (g), type of benefits (w) and place of residence (R)

$upb_{g,w}^{R} = UPBQ_{g,w}^{R} upc_{g,w}^{R}$..................or..........$upbrgw =$
$UPBRGWQ\#upcrgw$..(IV.b)

Number (u) of physician (p) benefits (b) by gender, age and education (g), type of benefits (w) and place of residence (R)

$upb_w^R = \sum_g upb_{g,w}^R$.........................or...........$upbrw =$
$i\_G'\#'upbrgw$.....,...(IV.c)

Number (u) of physician (p) benefits (b), by type of benefits (w), department (o) and place of residence (R)

$upb_{w,o}^R = UPBOQ_{w,o}^R upb_w^R$..........or..............$upbrwo =$
$UPBRWOQ"\#"upbrw$..(IV.d)

Number (u) of physician (p) benefits (b), by type of benefits (w), department (o) and place of commodity market (s)

$upb_{w,o}^S = \sum_r UPBQ_{w,o}^{R,S} upb_{w,o}^R$...............or..............$upbswo =$
$UPBRSWOQ'\#'upbrwo$.................................(IV.e)

Cost (cor) of physician (p) benefits (b) by type of benefits (w) by department (o) and place of commodity market (s)

$corpb_{w,o}^S = CORPBSQ_{w,o}^S upb_{w,o}^S$...............or................$corpbswo =$
$CORPBSWOQ\#upbswo$......................(IV.f)

Cost (cor) of physician benefits (p) by type of benefits (w) and by place of commodity market (s)

$corp_o^S = \sum_w corpb_{w,o}^S \dots\dots\dots\dots\dots\dots\dots\dots\ or \dots\dots.\dots\dots.\ corpso =$
$i\_w'\#'corpbswo$....................................(IV.g)

Governmental consumption (cor) of physician benefits (p) by detailed sector (jd) and place of commodity market (s)

$corp_{jd,j=prax}^S = \sum_o CORPQ_{o,jd}^S corp_o^S$............or........$corpsjd =$
$CORPSOJDQ'\#'corpso$.............................(IV.h)

Governmental consumption (cor) of physician benefits (p) by commodities (i) and place of commodity market (s)

$corp_{i,i=prax.com}^{S,f} = \sum_o CORPFQ_{o,i}^S corp_o^S$.........or........$corpsif =$
$CORPSOIFQ'\#'corpso$..............................(IV.i)

Social care activities:

Persons (u) in contacts (c) with care system (c) by gender, age and education (g), type of benefit (w) and place of residence (R)

$ucc_{g,w}^{R} = UCCQ_{g,w}^{R}u_{g}^{R}$........................or...........$uccrgw = UCCRGWQ\#urg$
....(V.a)

Number (u) of care (c) benefits (b), by gender, age and education (g), type of benefit (w) by place of residence (R)

$ucb_{g,w}^{R} = UCBQ_{g,w}^{R}uc_{g,w}^{R}$..................or..........$ucbrgw =$
$UCBRGWQ\#uccrgw$..(V.b)

Number (u) of care (c) benefits (b) by type of benefits (w) and place of residence (R)

$ucb_{w}^{R} = \sum_{g} ucb_{g,w}^{R}$.........................or...........$ucbrw =$
$i\_G'\#'ucbrgw$.....,..(V.c)

Number (u) of care (c) benefits (b), by type of benefits (w), department (o) and place of residence (R)

$ucb_{w,o}^{R} = UCBOQ_{w,o}^{R}ucb_{w}^{R}$..........or.............$ucbrwo =$
$UCBRWOQ"\#"ucbrw$..(V.d)

Number (u) of care (c) benefits (b), by type of benefits (w), department (o) and place of market (s)

$ucb_{w,o}^{S} = \sum_{r} UCBQ_{w}^{R,S}ucb_{w,o}^{R}$..............or...............$ucbswo =$
$UCBRSWOQ'\#'ucbrwo$.....................................(V.e)

Cost (cor) of care (c) benefits (b) by type of benefits (w) by department (o) and place of commodity market (s)

$corcb_{w,o}^{S} = CORCBSQ_{w,o}^{S}ucb_{w,o}^{S}$...............or................$corcbswo =$
$CORCBSWOQ\#ucbswo$...........................(V.f)

Cost (cor) of care benefits (c) by type of benefits (w) and by place of commodity market (s)

$corc_{o}^{S} = \sum_{w} corcb_{w,o}^{S}$ … … … … … … … … or … … . … … . $corcso =$
$i\_w'\#'corcbswo$.......................................(V.g)

Governmental consumption (cor) of physician benefits (p) by detailed sector (jd) and place of commodity market (s)

$corc_{jd,j=care}^{S} = \sum_{o} CORCQ_{o,jd}^{S}corc_{o}^{S}$...........or.................$corcsjd =$
$CORCSOJDQ'\#'corcso$........................(V.h)

Governmental consumption (cor) of physician benefits (p) by commodities (i) and place of commodity market (s)

$corc_{i,i=care.com}^{S,f} = \sum_o CORCFQ_{o,i}^{S} corc_o^S$.........or..................$corcsif =$
$CORCSOIFQ'\#'corcso$.......................(V.i)

Educational activities:

Stock (u) of students (e) by gender, age and education primo (gp), ongoing education primo (wp) and ultimo (wu) and place of residence (R)

The population (u) by gender, age and education primo (gp), and education ultimo (gu) the year before (t-1) by place of residence (R)

$u_{gp,t}^{R} = u_{gu,t-1}^{R}$................................or...............................$urgp = urgu(t-1)$
....(VI.a)

Stock (u) of students (e) by gender, age and education primo (gp), ongoing education primo (wp) and place of residence (R)

$ue_{gp,wp}^{R} = UEQ_{gp,wp}^{R} u_{gp}^{R}$...... ....or...........$uergpwp = UERGPWPQ\#urgp$ ......
....(VI.b)

Results of eductional activities in the population (u), who are students (e), by gender, age and primo education (gp), ongoing education (w) and ultimo education (gu) by place of residence (R)

$ue_{gp,wp,gu}^{R} = UEQ_{gp,wp,gu}^{R} ue_{gp,wp}^{R}$.....or. ....$uergpwpgu = UERGPWPGUQ\#uergpwp$..
...............(VI.c)

The population (u), who are students (e) and PASSES exam (f) by gender, age (gp) and by NEW ultimo education (gu) by place of residence (R)

$uefNEW_{gu}^{R} = \sum_{gp,wp,gu=wp} UEFQ_{gp,wp,gu}^{R} ue_{gp,wp,gu}^{R}$................Or

$uefNEWrgu =$
$UEFRGPWPGUQ'\#'uergpwpgu$..
...............(VI.d.1)

The population (u), who are students (e) and PASSES exam(f) by gender, age and by OLD primo education (gp) by place of residence (R)

$uefOLD_{gu}^{R} = \sum_{gp,wp,gu\neq wp} UEFQ_{gp,wp,gu}^{R} ue_{gp,wp,gu}^{R}$...........or

$uefOLDrgu =$
$UEFRGPWPGUQ'\#'uergpwpgu$...(VI.d.2)

The population (u) by educational level primo(gp)/ultimo (gu) by new (NEW) and old (OLD) educational levels, by place of residence (R)

$u_{gu}^{R} = u_{gp}^{R} + uefNEW_{gu}^{R} - uefOLD_{gu}^{R}$...or....$urgu = urgp + uefNEWrgu - uefOLDrgu$................(VI.e)

The population (u), who are students (e) by ongoing education (wp) by place of residence (R)

$ue_{wp}^{R} = \sum_{gp} ue_{gp,wp}^{R}$............or...........$uerwp = i\_gp'\#'uergpwp$..(VI.f)

Stock (u) of students (e) by ongoing education primo (wp), education branch (o) and place of residence (R)

$ue_{wp,o}^{R} = UEWPOQ_{wp,o}^{R} ue_{wp}^{R}$...... ....or...........$uerwpo = UERWPOQ"\#"uerwp$ ....(VI.g)

Number (u) of students (e), by ongoing education primo (wp), education branch (o) and place of market (s)

$ue_{wp,o}^{S} = \sum_{r} UEQ_{wp,o}^{R,S} ue_{wp,o}^{R}$...............or...............$ueswpo = UERSWPOQ'\#'uerwpo$.................................(VI.h)

Cost (cor) of educational activities (e)by type of ongoing education primo (wp) and education branch (o) and place of commodity market (s)

$core_{wp,o}^{S} = CORESQ_{wp,o}^{S} ue_{wp,o}^{S}$.............or.................$coreswpo = CORESWPOQ'\#'ueswpo$.... ....(VI.i)

Cost (cor) of education activities (e) by education branch (o) and by place of commodity market (s)

$core_{o}^{S} = \sum_{wp} core_{wp,o}^{S}$ … … … … … … … … … or … … . … … . $coreso = i\_wp'\#'coreswpo$..................................(VI.j)

Governmental consumption (cor) of physician benefits (p) by detailed sector (jd) and place of commodity market (s)

$core_{jd,j=educ\ branch}^{S} = \sum_{o} COREQ_{o,jd}^{S} core_{o}^{S}$............or........$coresjd = CORESOJDQ'\#'coreso$..................(VI.k)

Governmental consumption (cor) of physician benefits (p) by commodities (i) and place of commodity market (s)

$core_{i,i=care\ com.}^{S,f} = \sum_{o} COREFQ_{o,i}^{S} core_{o}^{S}$.........or........$coresif = CORESOIFQ'\#'coreso$...........................(VI.l)

8 References

Leontief, W.W., 1936. Quantitative input and output relations in the economic systems of the United States. *The review of economic statistics*, pp.105-125.

Leontief, W. (1966) Input-Output Economics (New York, Oxford University Press).

Madsen, B. & Clausen J. (2017): "Labor market for health care professionals (HCP) in for the Capital Region of Denmark towards 2025".

Madsen, B. (2009): *Regional Economic Development from a Local Economic Perspective – A General Accounting and Modelling Approach*, Doctoral Dissertation, Department of Geography and Geology, University of Copenhagen, CRT.

Madsen, B and C. Jensen-Butler (2004): *Theoretical and operational issues in sub-regional modelling, illustrated through the development and application of the LINE model,* Economic Modelling, Volume 21, Issue 3, p. 471-508.

Madsen, B. and C. Jensen-Butler (2005): Spatial Accounting Methods and the Construction of Spatial Accounting Matrices. *Economic Systems Research*, vol 17, 2005.

Madsen, B. and J. Zhang (2010): *Towards a New Framework for Accounting and Modelling the Regional Impacts of Tourism and Culture,* Economic Systems Research, 2010, Vol. 22(4), December, pp. 313–340.

Miller, R.E. and Blair, P.D., 2009. *Input-output analysis: foundations and extensions*. Cambridge university press.

Miyazawa, K. (1966): Internal and external matrix multipliers in the input-output model. *Hitotsubashi Journal of Economics* 7: 38-55.

Miyazawa, K. (1968): Input-output analysis and interrelational income multiplier analysis. *Hitotsubashi Journal of Economics* 7: 39-58.

Miyazawa, K. (1976): *Input-output Analysis and the Structure of Income Distribution*.

Nijkamp, P., Rietveld, P. and Snickars, F., 1987. Regional and multiregional economic models: a survey. In *Handbook of regional and urban economics* (Vol. 1, pp. 257-294). Elsevier.

Organisation for Economic Co-operation and Development, OECD Health Statistics 2018.

Rutten, M. and Reed, G., 2009. A comparative analysis of some policy options to reduce rationing in the UK's NHS: Lessons from a general equilibrium model incorporating positive health effects. Journal of Health Economics, 28(1), pp.221-233.

The European Commission (2014). *Health and social services from an employment and economic perspective*. EU Employment and Social Situation. [online] Luxembourg.

Available at: https://ec.europa.eu/social/BlobServlet?docId=13354&langId=en [Accessed 15 Mar. 2019].

The Ministry of Health (2017) Healthcare in Denmark – An Overview. Version 1.2. ISBN: 978-87-7601-365-3. Publication available: https://www.healthcaredenmark.dk/media/1479380/Healthcare-english-V16-decashx-3.pdf [Accessed 9 Aug. 2019].

Madsen, B., Clausen, J. and Virtanen, L. (2019) The welfare version of LINE - A Technical Documentation, The Capital Region of Denmark & CRT-report, Copenhagen, Denmark, Draft.

Zurn, P., Dal Poz, M.R., Stilwell, B. and Adams, O., 2004. Imbalance in the health workforce. *Human resources for health*, *2*(1), p.13.