Methodology of the Multiregional Health Account for Germany - An Iterative Algorithm-Based Multiregionalization Approach of Supply and Use Tables with Emphasis on Health

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May 2017

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Version: May 2017

Abstract: The Multiregional Health Account is a methodological enhancement of the National Health Account for Germany. The latter represents an established and annually updated satellite account quantifying the economic contribution of the health economy in terms of gross value added, employment and international trade. Its methodological enhancement to a multiregional framework for the 16 federal states of Germany is represented by multiregional supply and use tables. This setting allows to compile a multiregional health input-output table and subsequently to carry out input-output analysis. Hence, we are able to quantify the direct and indirect economic impacts of the health economy to analyze interdependencies between industries and federal states. For the purpose of compiling the Multiregional Health Account, we elaborate a new approach based on the SUT-RAS algorithm (Temurshoev & Timmer, 2011), which we adapt for the multiregional framework. We call it the MR-SUT-RAS algorithm. The methodology and its application in the context of the health economy is the subject of this contribution.

JEL Classification: C67, E01, I11, I18, R15

Key words: Input-Output analysis, regionalization, multi-regional supply and use tables, SUT-RAS, health economy, Germany

Acknowledgements: Thanks to the Federal Ministry for Economic Affairs and Energy of Germany for supporting earlier projects on the National Health Account and their interest in the further development into a multiregional framework. In addition, willingness of the Statistical Offices of the Laender to cooperate is highly appreciated as they provided additional and non-published data, which assures a higher quality of results. Moreover, data on regional health expenditures from our project partner BASYS made it possible to put the focus on health to this extent. We would also extend our thanks to WifOR giving us the opportunity to work on this topic as well as to our colleague Benno Legler for his support throughout the years of development.

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1 Introduction

First approaches to compile a German satellite account for health were implemented already from the late 1980s on (Geigant et al. 1986; Essig & Reich, 1988; Sarrazin, 1992; Henke et al., 2010; Ostwald et al., 2014; BMWi, 2015; Schneider et al., 2016). Those had the national health economy in the focus of studies and differed significantly in the definition of the subject of concern, the underlying database, approach or statistical standards compared to what is called the National Health Account for Germany (NHA) nowadays (BMWi, 2016; BMWi, 2017a).

The NHA is itself subject matter of further developments and methodological improvement (Schwärzler & Kronenberg, 2017). Its purpose is to elute the health economy from the overall economy without disrupting or overburdening the overall system. The underlying database refers to supply and use tables from national accounts. This way, the NHA demonstrates the contribution of the health economy to gross value added (GVA), employment and international trade. From 2010 on, the Federal Ministry for Economic Affairs and Energy has been the main initiator of these research activities with the purpose of pointing out the economic relevance of the health economy (Henke et al., 2010; Ostwald et al., 2014; BMWi, 2015, 2016, 2017a; Schneider et al., 2016). This enforced the ongoing paradigm shift, which promotes the supply of health as an important driver of economic growth, employment and trade and does not focus exclusively on the cost perspective of healthcare.

The most recent results confirm the importance of the health economy for the overall economical dynamics (BMWi, 2017a). In 2016, the health economy contributes 12.0 percent of overall GVA, 16.1 percent of German employment and 8.2 percent of exports. Therefore, GVA generated by the German health economy approximately equals Austrian overall GVA, employs 7 million people and is the third most important export industry of Germany. The significance of the industry has increased throughout the years from 2005 on and it acted as a stabilizer of the economy in times of the crisis (BMWi, 2017a, Hesse, 2013). The results also show the high heterogeneity that characterizes the health economy, which is caused by the composition of this cross-sectoral industry. It does not only comprise health services but also the manufacturing of medicine and medical technology next to a number of further products involved in healthcare. Therefore, the overall characteristic and development of the sector is influenced by various economic factors. The established NHA allows to track and analyze the impacts different subsectors of the health economy have on GVA, employment and trade.

Moreover, first evaluations have indicated towards a high heterogeneity regarding regions and the federal states of Germany (Ostwald et al., 2015a; Ostwald et al., 2015b; Ostwald et al. 2014, 2015c; Ostwald & Schwärzler, 2015; Ranscht, 2009; AG GGRdL, 2016; Schneider, 2013, 2014; BASYS, GÖZ, 2012). These studies, however, did not aim to apply the methodology derived for the compilation of the NHA. The rationale for this is that official statistical institutions of Germany do not provide regional supply and use tables, which is a basic prerequisite for the compilation. However, only regional supply and use tables in the same level of detail as used for the national calculations ensure results consistent with the established national approach.

In general, the high heterogeneity of the health economy in federal states observed within the aforementioned named studies calls for a deeper analysis in this context. In order to provide consistent results with the NHA, we first compile multiregional supply and use tables for the 16 federal states of Germany based on the same special evaluation of national accounts, which has also been used to calculate the NHA. The choice to compile one multiregional supply and use table each instead of 16 single regional supply and use tables is motivated by methodological considerations. The multiregional framework provides the possibility to compile 16 supply and use tables within one harmonized framework, which enhances the validity of results. Moreover, it reveals the modelled individual interconnectedness of federal states to each other. This enables input-output analysis with respect to the dependencies between individual federal states. The underlying compilation approach is in the center of this contribution.

In order to multiregionalize supply and use tables of the German economy we elaborate a methodology based on the concept of SUT-RAS (Temurshoev & Timmer, 2011). This approach was in its origins devised for another purpose, namely updating supply and use tables on the national level. We develop this approach further to make use of the concepts in a multiregional context. The iterative calculations assure balancing conditions of supply and use to be held by taking into account regional industry and product-specific information. Since it is closely related to the SUT-RAS algorithm, we call it the MR-SUT-RAS algorithm.

The MR-SUT-RAS has already been applied once in order to evaluate the direct effects of the health economy (BMWi, 2017b). The respective study evaluated the product-sided defined health economy of the 16 German federal states for the time horizon of 2006 until 2015 having available only two sets of supply and use tables for 2010 and 2011. It shows reasonable results over temporal progression and regional characteristics and therefore supports the developed approach (Schwärzler & Kronenberg, 2017b). Future steps involve to calculate the multiregional health input-output table in order to analyze dependencies within and among federal states (Schwärzler & Kronenberg, 2017c) with the main goal to implement results in political decision making (Schwärzler & Kronenberg, 201d). Focus of this paper is, however, the methodology of the Multiregional Health Account for Germany in order to trigger a discussion concerning the approach.

The remainder of this paper is structured as follows: In section 2 we describe the motivation of the MRHA. This includes reasons to calculate a MRHA including the background of the heterogeneous characteristic of the regional health economy and one possible field of application of the MRHA. Section 3 focusses on the methodological background of the approach. It describes specifics of the satellite account approach, points out differences to existing regionalization methodology and introduces the reader to the basic multiregional context. In section 4 we discuss the methodological approach itself before we draw conclusions in section 5.

2 Motivation

The established NHA shows heterogenetic effects with regard to national GVA, employment and international trade among certain fields of the health economy (BMWi, 2017a). Previous studies for different regions found a high degree of specifics among the federal states under review as well (Ostwald et al. 2015a; Ostwald et al. 2015b; Ostwald et al. 2014, 2015c; Ostwald & Schwärzler, 2015; Ranscht, 2009; AG GGRdL, 2016; Schneider, 2013, 2014; BASYS & GÖZ, 2012). The established MRHA confirms the high heterogeneity among regions concerning the direct effects of the health economy on GVA, employment and international trade for the first time based on the methodology developed on the national level (BMWi 2017b). In this section, we focus on historic and political reasons causing these differences and making an in-depth analysis of the regional health economy necessary. In addition, we describe a field of application, in which the MRHA could prove as a useful analysis tool.

Care structures have a high impact on the characteristics of the health economy within a federal state. These structures of inpatient and outpatient care supply have developed historically in Germany. In East Germany, outpatient care was mainly characterized by public and operational organized supply within polyclinics and outpatient clinics before the Unification of Germany in 1989. As of that year, outpatient care was adapted to health care supply provided by private suppliers in terms of resident doctors. (RKI, 2014)

Moreover, there are significant differences between federal states in terms of their supply density of health care. Supply density of health care in terms of doctors per inhabitant is highest for the city states Berlin, Bremen and Hamburg. To some extent, this is certainly promoted by health care supply for the population in the catchment area of these city states. But also Bavaria and Saarland exhibit considerably above average values of doctors per inhabitant, while federal states from the Eastern part of Germany and Lower Saxony show the lowest rates. Yet, the new Länder of Germany exhibit the highest increase of this indicator since 1991. (Klose & Rehbein, 2015)

Next to disparities caused by geographical circumstances the availability of a skilled workforce and financial resources influences the development and structure of the health economy. Certain occupational groups of the health economy, such as medical doctors, certified nurses, medical engineers, orthopedic and rehabilitation technicians exhibit a significant and partly region-specific growing scarcity of skilled workforce already today. (BA, 2016; Ostwald et al., 2016)

Furthermore, there happens to be a heterogeneity concerning the availability of financial resources, which impacts on inpatient facilities. Recent and past funding programs such as the Health Structure Act (SVRG, 2014), promoted a modernization of hospitals in Eastern Germany after the Unification of Germany. Regional differences appear with respect to investments made (DKG, 2015) and investments necessary (RWI, 2014).

The necessity for investments to be undertaken in hospitals is linked to the demographic development in the respective federal state. Increasing age leads to a rise of health problems in terms of the number of people affected and the complexity of diseases (Destatis et al., 2009). This leads to an increase in the demand for health services and health-related products (Kronenberg, 2009, 2011). Demographic change therefore requires an efficient health system (RWI, 2015). Yet, federal states are affected in different ways in this matter: Senior citizens make up 6.4 percent of the population in most sub-regions of Saxony, whereas they make up only 4.8 percent in large parts of Bavaria (IEGUS & RWI, 2015).

Increased needs for health care supply caused by demographic change affects the regional distribution of doctors as well. A demographic factor was recently introduced into the distribution mechanism of doctors carrying out outpatient treatment in order to react on regional differences concerning the number of elderly people (KBV, 2016; GBA, 2016). The effects of regionally differentiated demographic change has been studied with input-output techniques in earlier work (Kronenberg & Engel, 2008; Kronenberg et al., 2010). However, these studies relied on individual input-output tables for single regions and were therefore unable to account for interregional spillover effects. This shortcoming is one of the motivations for the multiregional approach developed in the present paper.

Moreover, industrial specializations of the health economy are distributed in a heterogeneous way across Germany similarly to the overall industrial structure. This causes differences in international and national openness of federal states, which impacts on dependencies and economic spill-over effects.

The MRHA provides a consistent data base, which quantifies the health economy of German federal states within one model, thereby using the same methodology to establish this satellite account that was used for the national calculations. Therefore, it becomes possible to analyze existing heterogeneities among the federal states in the context of the contribution to GVA, employment and trade of the respective health economy. In the following, we describe one field of application of the MRHA, which points out the political relevance of the established tool.

Due to the dualistic financing framework of the health system in Germany (BMVJ, 1972), both health insurance companies and federal states have to bear costs caused by health care supply. While the former are responsible for current expenditures, the latter institutions have to come up for the costs of building, maintaining and equipping hospitals with medical technology.

This framework of health care financing leads to challenges for federal states and results in a cumulated investment bottleneck in hospitals said to amount between 14.6 Bn. € (Augurzky et al., 2014) and 50 Bn. € (DKG, 2014), depending on the author of the specific study and the definitions used.

This significant investment bottleneck and a regional heterogeneity of actual investments taken represent severe challenges in the light of ensuring equal standards regarding the equipment with medical technology and consequently needs-based health care supply. Future challenges, such as demographic change, the debt brake (SVRG, 2014) and the end of the investment program for hospitals in Eastern Germany's federal states at the beginning of 2015 (BMG, 1992) may toughen the already existing challenge. The relevance of the topic and its political awareness are illustrated by its addressing within the recently published revision of the hospital structure act (BMG, 2015). Numerous statements however stress the inadequacy of incorporated approaches (DGGÖ, 2015).

Up to now, there is no compensation mechanism between federal states, which addresses this challenge. While the morbidity-oriented risk structure compensation focusses on current expenses borne by health insurance companies solely, the German Federal Financial Equalization System (*Länderfinanzausgleich*) does not consider factors such as demographic composition or status of health (Ulrich & Wille, 2014; National Association of Statutory Health Insurance Funds, 2015; BMF, 2013; Rürup B., 2008).

Due to existing interdependencies between federal states, we hypothesize that some regions even profit from a higher demand for health care in cases they supply the rest of the country with products and services necessary for patient treatment. Interdependencies among regions hence result from the production and provision of medication, medical products and other goods and services – produced in one region and consumed in another region.

In the course of the application of the MRHA, we conduct input-output analysis to reveal the interconnectedness of federal states caused by patient treatment. Based thereon, we derive federal-specific contribution amounts to a fund for the specific purpose to cope with lagging hospital investments. The individual contribution to the fund is derived from federal states' profits from patient treatment in the rest of the country.

3 Methodological background

Within this section, we describe the methodological background of the MRHA in order to facilitate a better understanding of section 4 and the quality of results. Attention should be paid on the fact that the presented methodology concentrates on a general multiregionalization of a set of supply and use tables of national accounts, but superior emphases are put on the health economy in selected cases. The subsequent step - the compilation of a multiregional health satellite account from an overall economic multiregional account - follows national standards and is described in detail in Schwärzler, Kronenberg (2017a). The remainder of this section is structured as follows:

Subsection 3.1 describes the principles and specifics of the NHA and therefore the MRHA. In subsection 3.2, we address the characteristics of our approach and compare it to existing methodology on (multi)regionalization. Subsection 3.3 focusses on the general multiregional framework.

3.1 Principles of the multiregional and national health account

Within this subsection, we describe the basic principles of the NHA, which were developed throughout the several projects on the national level. As we apply the same methodology to calculate the MRHA, the principles described in the following count for the MRHA as well. Detailed information on how to compile the NHA as well as background information can be found in Schwärzler & Kronenberg (2017a). However, in order to facilitate a better understanding of the explanatory power of the NHA and MRHA, a short overview of principles and the approach is given over here.

The health economy in the context of the NHA is specified in accordance to a definition established in 2005. It refers to the health economy as '[…] the production and marketing of goods and services, which serve for prevention as well as for the provision of health and for rehabilitation.' (BioCon Valley, 2005). At this point it is essential to note the focus on goods and services related to health in contrast to involved agents. Consequently, one good or service is part of the health economy, if it serves a better status of health or prevents its deterioration, regardless of who produced and financed it. This makes clear why the set of supply and use tables is essential for the calculations of the NHA and the MRHA. Supply and use tables provide data on the product-side as well, while most key indicators of national accounts such as GVA and employment refer to the industry side exclusively.

The health expenditure survey serves as a main secondary data base to quantify the so-called 'core area' of the health economy. It also follows a product-specific approach in accordance with international standards (OECD, Eurostat, WHO, 2011). In order to quantify the economic output of the product-sided defined health economy, we match the consumer side of the use table with product-sided defined expenditures from the health expenditure survey. This makes it possible to analyze the health economy in a most valid way in terms of definition and quantification. The 'extended area' of the health economy, however, does not refer to any comparable secondary data base or international standard but comprises products and services, which are of main concern to the health economy beyond the definition of the health expenditure survey, i.e. E-Health, R&D or health tourism.

Special evaluations of national supply and use tables, provided by the Federal Statistical Office, serve as the basis for the NHA and accordingly the MRHA. Its uniqueness lies in the detailed dimension of tables, representing 930 partly or fully health related goods out of 2.643 products and services, which make up the overall economy in German national accounts. For the current calculations we have available supply and use tables in this detail for the years 2010 and 2011. Tables refer to domestic production and imports separately at basic prices. Most recent statistical standards such as NACE 2008 and ESA 2010 apply. Based on this, we calculate national health satellite accounts comprising of health-specific supply and use tables for several years. In order to calculate data on the health economy for the time horizon of 2005 until 2016 we make use of the SUT-RAS algorithm. This way we project the special evaluation on supply and use tables referring to 2010 and 2011 for the desired years. Based on the health-specific supply and use tables we calculate a health-specific input-output table.

3.2 Differences to existing methodology for the regionalization of national accounts

Throughout the last years there has been an increasing interest in regional input-output tables for scientific research. In matters of compilation and data availability it is essential to differentiate between regional tables involving several nations in contrast to input-output tables on the subnational level. Usually, poor data availability of the regions in consideration poses a central challenge to the compilation of the latter. Consequently, survey based input-output tables on the subnational level are hardly available, as high expenses result from the collection and processing of data. Scarcity of data especially occur with regard to interregional trade flows, information on production technology and resulting input-output coefficients. To overcome the difficulties resulting from the absence of survey-based regional input-output tables it is suggested to compile input-output tables based on non-survey or hybrid approaches. This facilitates insights into macroeconomic characteristics of economic activities of subnational regions.

The most common approach to regionalize IO tables are locations quotients, from which FLQ and AFLQ perform best (Bonfiglio & Chelli, 2008). Those approaches are most suitable for type B tables (Kronenberg 2012).[2] Even if those approaches show reasonable results for single regional tables, FLQ and AFLQ depend on a variable parameter, which has to be chosen for the calculation and has high impacts on the results. Literature also shows that neglecting the existence of cross hauling leads to unsatisfactory results (Többen & Kronenberg, 2015) and consequently overestimated input-coefficients.

Cross-hauling is considered by the methodological approach of CHARM (Kronenberg, 2009). This approach is most suitable for type E tables.[3] However, especially in the case of small regions the approach does not always produce reasonable results due to assumptions made in association with national patterns (Flegg et.al, 2015). CHARM has also been extended to multiregional applications (Többen & Kronenberg, 2015).

Schröder & Zimmermann (2014) used both CHARM and location quotients for calculating intraregional output multipliers for a German region. Differences between results are considerably high. This fact

[2] Type B tables focus on national demand and production and involve international imports only as necessary supplement at the edge of tables.

[3] Type E tables represent supply and use as the sum of domestically produced and imported goods.

stresses the challenge to derive realistic regional input-output tables especially in cases when no survey based tables are available to evaluate their accuracy.

From a traditional point of view, input-output tables have been used as a starting point for regional or interregional impact analysis instead of supply and use tables. However, recent literature shows that the framework of supply and use tables is preferable over input-output tables. There are a number of reasons for that. Supply and use tables are based on the methods used by the statistical offices to compile national accounts and therefore refer directly to the collected data (Madsen & Jensen-Butler, 1999). Consequently, supply and use tables are not affected by technology assumptions applied to derive IO tables.

A further advantage of this concept is the classification of tables with respect to both categories of industries and products, which enhances incorporating additional information significantly (Lenzen & Rueda-Cantuche, 2012). Furthermore, the square format of input-output tables is considered with an essential loss of information, as the rectangular shape of supply and use tables has to be aggregated first in order to compile a square input-output table.

Moreover, data availability makes the set of supply and use tables to be the preferable database for regionalization in the special case of German federal states. Information on GVA, output and employment refer to categories of industries and represent important information for the supply and use framework. This information is not available in categories of products, referring to the input-output framework. Consequently, available fundamental data cannot be integrated into the input-output concept without making further assumptions. We consider this as a critical argument against the regionalization of input-output tables, as assumptions concerning the most fundamental database used can have high impacts on the results. This circumstance can be avoided by making use of the supply and use framework.

One challenge, however, comes along with applying regionalization approaches on supply and use tables. Balancing conditions of supply and use have to be contained or at least restored. Similar problems arise when implementing hybrid approaches to regionalize input-output tables. The common way to calculate hybrid subnational multiregional input-output tables is to model the necessary set of single region tables by making use of non-survey methods. In a further step, they are linked to each other by including estimates on interregional trade (Többen & Kronenberg, 2015). Adjustments become necessary in order to include external information or to assure accounting identities. Mostly, optimization techniques are performed in order to minimize the differences between the non-survey table and the final table. Conversely, this means that the input-output table and hence multipliers are likely to be affected by the specific non-survey technique used (Bonfiglio & Chelli, 2008).

As a result from the previous description, we devise a new approach to calculate regionalized input-output tables, called MR-SUT-RAS. The procedure is based on the known concept of SUT-RAS (Temurshoev & Timmer, 2011), which had in its origins been developed for simultaneously updating national supply and use tables by assuring accounting identities without necessarily specifying any information on the product side. It therefore behaves unlike RAS and its relatives. This iterative algorithm considers secondary information already during compilation, which makes additional balancing obsolete. We developed the concept of SUT-RAS further to make it suitable for the multiregional framework. This extension is essential in order to maintain consistency with the national supply and use tables as it preserves the row and column sums of the national table. To be more specific, in an n-regional framework, the row sum of each n-fold available good equals the row sum of the national table. The same applies for industry-specific information or information on final consumption patterns. The possibility of cross-hauling is explicitly accounted for within the approach. A multiregional input-output table is then calculated from multiregional supply and use tables.

Similar approaches such as RAS have already been applied to regionalize input-output tables. According to Miernyk (1976) however, results lack on accuracy. This rather mechanical approach misses economic logic, he says. We do not disagree at this point. Moreover, the mechanical approach - the logic of the economic cycle within a multiregional system of a number of supply and use tables - is exactly what our approach relies on. Goods and services, produced by one federal state, are made available for the global economy, where either the region itself, the world outside of the nation or other federal states require especially this product or service. Hence, we accomplish to balance the multiregional supply and use tables for each product of each federal state taking into account interregional trade flows. The latter are hence to some amount predetermined by what federal states produce and what they need. These interregional trade flows can be modelled with a higher accuracy if we implement available data on the use of products and services, such as international trade statistics of federal states. Since this approach balances the multiregional supply and use table it becomes obsolete to define row sums, which are hardly available and are a prerequisite to apply the conventional RAS. This circumstance counters another of Miernyk's concerns regarding regional input-output tables. He explicitly points out the challenges in changes which may arise from a reconciliation procedure. Wiebe & Lenzen (2016) also address the use of balancing techniques when obtaining multiregional IO tables.

Often, tables lack detailed information in cases a specific research question is applied. Under these circumstances, available data on national accounts have to be disaggregated first (Wenz, et al., 2015). This is not necessary in the context of our approach due to a special evaluation on national supply and use tables provided by the Federal Statistical Office. Information on supply and use tables is available for 930 health-related products and services from an overall amount of 2.643 goods, which make up the German economy. Non-health related information is available in an aggregated manner. In order to make use of this maximum of information, we compile the multiregional satellite account for the health economy on the basis of the detailed set of national supply and use tables.

In total, we are well aware of the fact that this hybrid approach cannot in any way contest a survey based multiregional table. The MR-SUT-RAS algorithm is rather seen as a new approach, which makes implementation of additional data and assumptions easily possible and addresses some weaknesses of earlier approaches.

However, implementing additional information does not always lead to better results of the model in cases the assumptions applied to make this information suitable violate the macroeconomic picture. At this point one must decide upon the goal of the model. Especially in the case of the newly developed approach, the concept of holistic accuracy (Jensen, 1980) is preferable. This does not reflect accuracy in each cell of the table, but it serves a 'mathematical portrait' interpretation of the table.

During compilation, we have experienced the difference and impact of partitive accuracy in contrast to holistic accuracy in the case of consumption patterns. The Income and Consumption Survey (EVS) corresponds to a sample survey on German household consumption conducted on behalf of the Federal Statistical office with a periodicity of five years (Destatis, 2005). Data corresponds to purchasers prices from the overall amount of domestic production and imports. Consequently, several assumptions have to be incorporated in order to implement this specific information cell-wise into the multiregional use tables at basic prices for domestic production and imports separately. This implies that data has to be transferred into basic prices and assumptions concerning the amount of international imports and imports from other federal states have to be made. Moreover, the concept of EVS corresponds to the resident in contrast to the domestic concept, whereas the latter is applicable for national accounts.

In the context of the MR-SUT-RAS we must decide particularly careful which additional secondary data we implement. On the one hand, i.e. EVS data proofs challenging, since we have to make several assumptions in order to apply it to our framework. Moreover, we lack on assumptions to adjust the deviating concept it refers to. On the other hand, the MR-SUT-RAS is an iterative algorithm, which considers additional information not only as a suggestions but takes it as completely given. Since household consumption accounts for big shares of the use side in some cases, the implementation of highly uncertain data - due to the several assumptions taken and the different concept applying – can cause the algorithm to develop into unrealistic directions.

In our case we tried to implement EVS data but it turned out it took the algorithm many more iterations to converge, which led to highly unreasonable results in the end. Consequently, we used this data for plausibility checks only. It turned out that consumption patterns of our final resulting tables show reasonable similarities to EVS data. Temurshoev & Timmer (2011) also address the circumstance of additional information not always improving resulting estimates. However, they do not dwell any further upon this matter at this point.

Summarized, data scarcity and the fact no subnational tables are produced in general due to high costs involved, make it is hard to investigate research in this field. Consequently, we see the application on health in a multiregional context as an opportunity to develop a proper assessment on the quality of results and the developed approach. This way, we can concentrate on the dynamics of the regional health economy and profit from our profound knowledge in this field resulting from several years of research.

3.3 The multiregional context

In this subsection we want to proclaim the fundamental dimensions and interrelationships of multiregional supply and use tables. In order to facilitate a better understanding, the following concentrates on a three region economy. However, a multiregional table for the 16 federal states of Germany consists of a 16 x 16 framework.

The multiregional use table, which is shown in Figure 1, pictures the interrelationships of the economy. Federal state one produces output by making use of intermediate inputs from international, regional (i.e. federal state one) or ‘national but not regional’ grounds (i.e. federal state two and three or ‘Rest of Country’

(RoC)). The same counts for goods and services for final consumption. They are either bought from international areas, are produced by the very same federal state in which it is consumed or are obtained from federal state two or three in a three region economy. Following this framework, the goods and services consumed or demanded for further production in federal state one can originate from four different areas in a three region economy, from which the latter three refer to imports: federal state one itself, federal state two, federal state three or international grounds. This results in national macroeconomic interrelationships between federal state one and the three regions of product origins as well as inter-sectoral interconnectedness within federal state one itself. Imports from federal state two or three to federal state one are shown within the bottom two squares in the left column of Figure 1, the sum of nine squares representing the overall national economy. Imports from international grounds are recorded within a row at the bottom. This is caused by the fact that national interdependencies are in the focus of tables but the framework is incomplete if imports from international grounds are ignored.

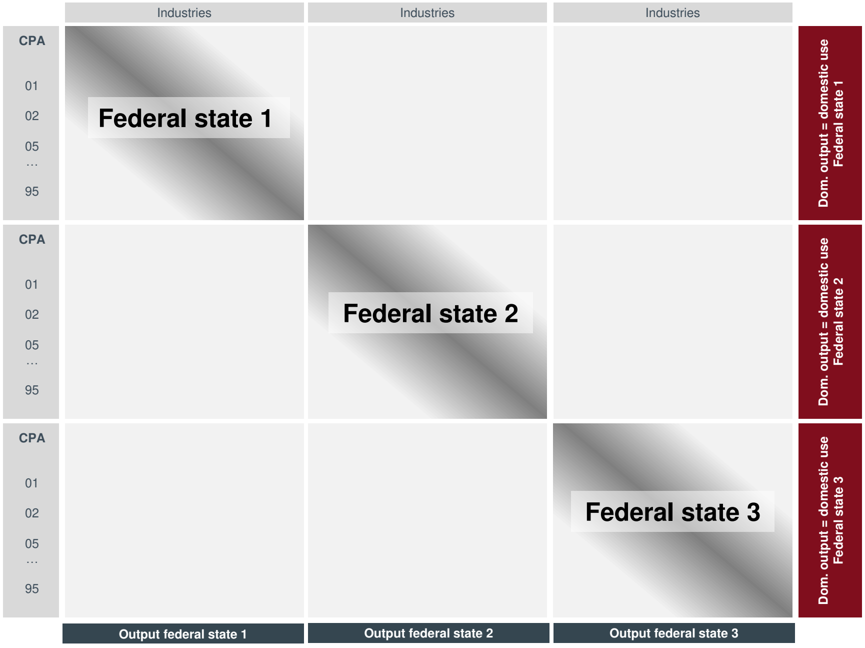
Figure 1: Multiregional use table in a 3 regional economy

Source: Own illustration.

In turn to the situation just described, interdependencies between federal state one and the other regions also arise from exports of federal state one to the other regions. This is the case when goods produced within one federal state are not consumed by the resident population or enterprises. Exports from federal state one to federal state two and three are shown within the right and the middle square of the top row of Figure 1.

Described linkages lead to interdependencies of production and consumption between federal states, which are shown within the multiregional use table. This circumstance may not be mixed up with the multiregional supply table shown in Figure 2, which reflects multiregional production structures. This figure shows three regional supply tables for a three region economy. This means a fundamental difference to the multiregional use table from Figure 1 exhibiting information on multiregional relationships in a 3x3 framework.

Figure 2: Multiregional supply table in a 3 regional economy



Source: Own illustration.

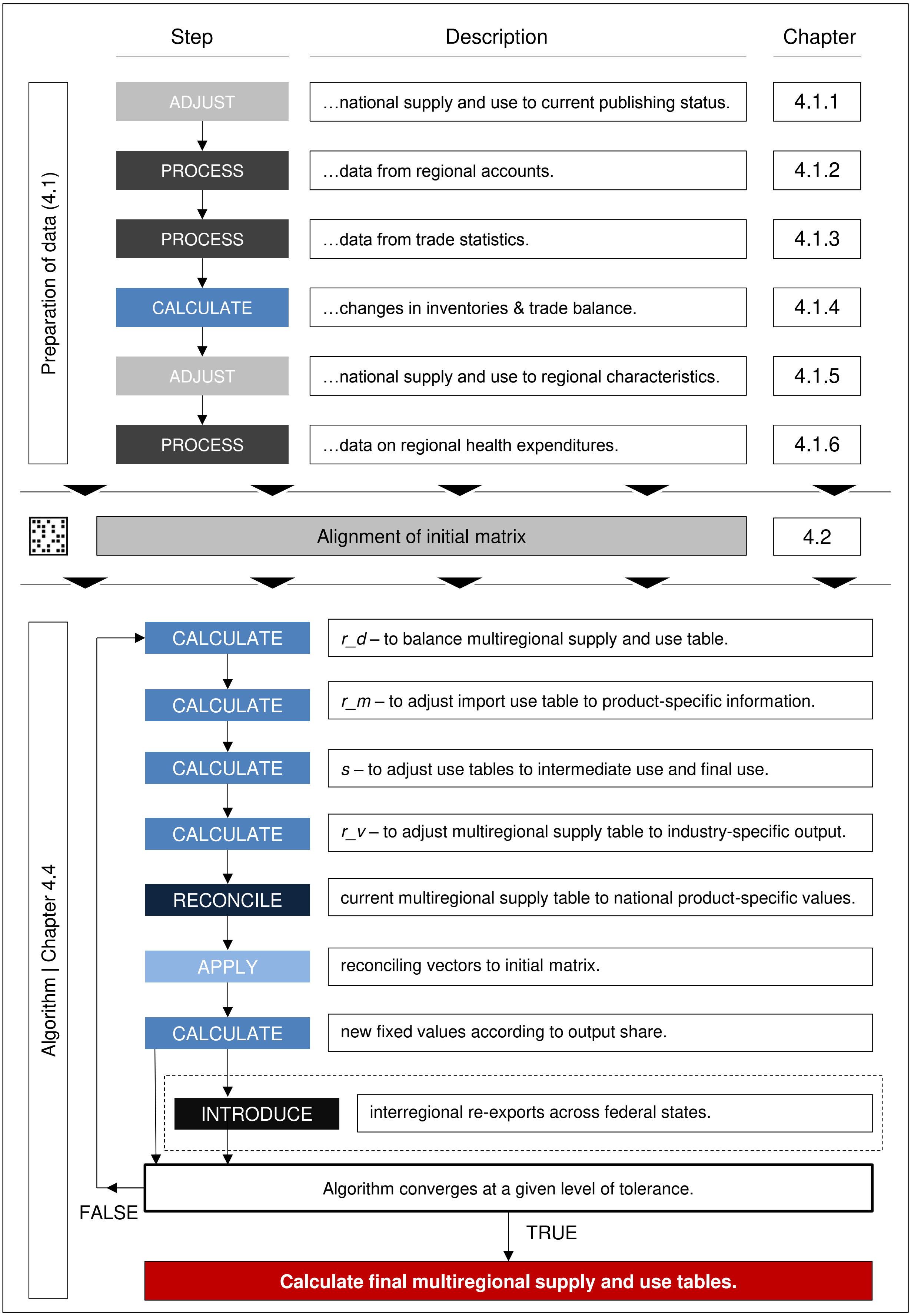
The regional supply tables of the multiregional model are arranged in the shape of a block diagonal matrix. There are only entries of zeroes in the off-block-diagonal areas since the allocation of regional economic key indicators such as output, GVA or employment refer to the local unit of enterprises rather than its technical unit in the case of multiregional operating companies.

Consequently, products and services produced within one federal state are always generated by regional enterprises and hence by employees working in this federal state. This circumstance is represented by shape of Figure 2, representing the multiregional supply table for the overall economy.

4 Compilation methodology

The motivation and the methodological background of the MRHA have been described in sections 2 and 3. The main contribution of this paper, the compilation approach of the MRHA, is discussed within this section. Subsection 4.1 focusses on used data and its preparation. In subsection 4.2 we describe the preparation and design of the starting point before applying the iterative algorithm to it. Subsection 4.3 focuses on the known concept of SUT-RAS, which is further developed to the multiregional framework in subsection 4.4. Subsection 4.5 comprises of a short description of results from applying the MR-SUT-RAS and opposes it with initial tables. In a final step, we describe the way of compiling the satellite account from the calculated set of multiregional supply and use tables in subsection 4.6. In Figure 3, the steps of compilation are summarized.

Figure 3: Steps of compilation



Source: Own illustration.

4.1 Preparation of data

The selection and preparation of data used for the compilation of the MRHA are an essential part of the overall calculation. There are numerous different data bases, which play a decisive role during the compilation: The special evaluation of supply and use tables represents a particular feature of the application as it comprises of very detailed and non-official information and represents the main underlying data base for the MRHA. Available data on regional accounts goes also beyond published data but needs further processing in order to be suitable for the compilation. Trade statistics on international export and import of federal states is a further essential source of information. In order to use a maximum of available data in this matter, we consulted two different data sources with different categorization and matched them. Data on changes in inventories and the overall amount of interregional trade are not available from official data. The derivation can however be conducted with regard to the missing amounts to close the economic circle. Data on health expenditure refer to private and public expenditure for health care services and products. Several assumptions needed to be made in order to implement this product-specific information.

4.1.1 Special evaluation of supply and use tables

The special evaluation of supply and use tables, provided by the Federal Statistical Office, comprises detailed information on the goods and services related to the health economy. Consequently, we have information on domestic use, domestic supply and import use at basic prices for 930 out of overall 2.643 products, which make up the German economy according to the national accounting framework. For the selected goods we have complete information. This amounts to information on 930 goods for 64 industries and seven categories of final consumption. Moreover, aggregated tables for supply and use are available, which enables us to calculate the aggregated values of missing data of the special evaluation. This way we have full information on the overall economy with selected areas of detailed information, referring to goods and services partially or fully related to the health economy. We have two sets of supply and use tables available, referring to the years 2010 and 2011. Statistical standards correspond to NACE 2008 and ESA 2010.

Substantial additional adaptations of this data base are not necessary as it represents the main fundament for calculating the MRHA. In fact, it is all other data that must fit this data base. However, in order to assure consistency of the present tables of national accounts with secondary data regarding regional accounts, it is essential to refer to the same date of publishing. The set of tables on supply and use were published in 2015, whereas the secondary data on regional accounts used are from 2016. We do not have available the set of data on regional accounts from an earlier publication date. Consequently, we update the available supply and use tables for the German economy in accordance to revised data published in 2016 making use of the original SUT-RAS algorithm (Temurshoev & Timmer, 2011). Data for this procedure refers to Destatis (2016a). For more information concerning this procedure see Schwärzler & Kronenberg (2016). The resulting slightly adjusted supply and use tables now fit the data of regional accounts, i.e. result in the same overall amount for the German economy.

4.1.2 Regional accounts

We use official but partially unpublished data of regional accounts on GVA, employment, intermediate consumption, compensation of employees and total amounts of the several categories of final use (VGRdL, 2016). As mentioned, we aim to compile the MRHA based on the special evaluation on national supply and use tables. Consequently, regional industry-specific information has to equal the level of aggregation on the national level, which is 64 industries and seven categories of final use. However, data available on regional GVA and employment refer to 38 aggregates of industries and five categories of final demand. The latter includes the sum of household final consumption expenditure (households and non-profit organizations serving households), government final consumption expenditure, investments in machinery, the sum of equipment and other products, and gross fixed capital formation in construction. Additionally, information on taxes less subsidies is available for the federal states of Germany. Intermediate consumption and compensation of employees refer to 21 aggregates of industries. In this section, we only concentrate on the derivation of GVA, output, intermediate consumption and compensation of employees into 64 aggregates.

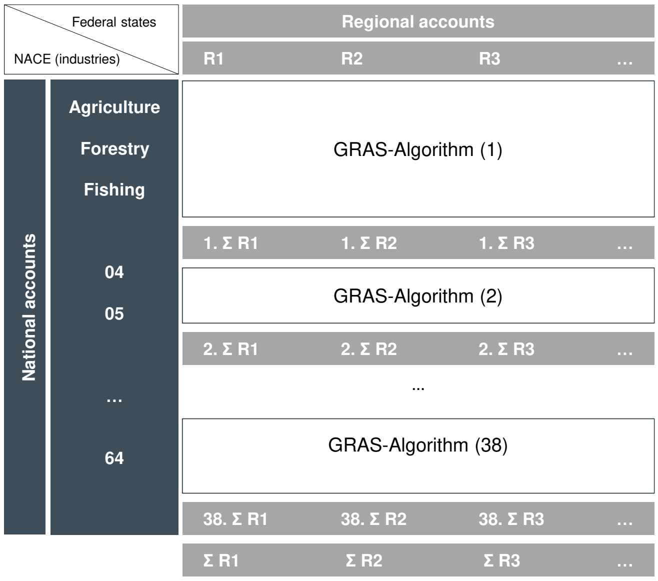
We proceed this way, since data on the overall amounts of final consumption categories except for exports and change in inventories are available from regional accounts and only need minor adjustments in the case of household final consumption expenditure. We differentiate the latter into households and non-profit organizations serving households by applying the national distribution. Since non-profit organizations serving households account for only 2.8 percent of overall household consumption, we think that this unsophisticated approach is acceptable. Information on international trade does not refer to regional accounts but to trade statistics. Hence we focus on that field in subsection 4.1.3 and do not discuss it any further over here. We address the derivation of changes in inventories and the amount of interregional trade, for which no data is data available, in subsection 4.1.4.

Up to three federal states did not provide data on GVA, employment and intermediate consumption at the same level of disaggregation as the other federal states of Germany did. Consequently, we use data on employees subject to social security contribution (BA, 2011) to derive missing information on employees from residual sums of regional accounts. Regarding GVA, we use available or calculated information on employees and weight this information with labor productivity in terms of GVA per employee from the next related aggregate in order to distribute the residual sum over the federal states of concern. We calculate missing data of intermediate consumption by applying national GVA quota in order to disaggregate the residual sum. We proceed accordingly, since no information on higher aggregates is available in this case.

After each step of disaggregation we conduct the GRAS algorithm (Lenzen et.al, 2007) on the resulting matrix of derived missing data. In order to facilitate a better understanding of this procedure we use the disaggregation of employees from 38 aggregates into 64 aggregates as an exemplary field of application in accordance to Figure 4.

Likewise to the previous procedure we use information on employees subject to social security contribution to derive first estimates on employees within each of the aggregates. For example, we have available data on the overall sum of employees working in agriculture, forestry and fishing for each of the federal states but want to derive each single amount for each of the federal states. We hence derive a matrix of first estimates on the distribution over agriculture, forestry and fishing for each federal state. However, the sum over federal states of employees working in agriculture deviates from the national sum in cases we are not able to derive the absolute exact distribution key, which is in general the case. Since we know the sum of each of the industries on national level and the aggregate sum of agriculture, forestry and fishing for each of the federal states, we know the row sums and the column sums the matrix of first estimates is supposed to match. Consequently, we reconcile this matrix in accordance to these target values by making use of the GRAS algorithm. We proceed this way for each of the 38 aggregates in the case of data on employees and GVA and for the 21 aggregates we have available for intermediate consumption and compensation of employees.

Figure 4: Consolidation of disaggregated regional accounts data



Source: Own illustration.

In order to derive first estimates for GVA, intermediate consumption and compensation of employees we use different approaches. As mentioned, we use information on employees subject to social contribution to derive a first estimation of employees. We disaggregate GVA in accordance to the employees derived, weighted with national values on labor productivity per industry. For a first estimate of intermediate consumption for 64 industries we apply the national GVA quota on existing 21 aggregates in order to obtain a first estimate on the disaggregation. Compensation of employees is available for 21 aggregates as well. As we know the national share of compensation of employees to GVA, we take this information in combination with calculated and consolidated data on GVA on the regional level. Again, we apply the GRAS method on each of the matrices referring to first estimates of disaggregation.

At the end of this procedure we have information on GVA, employees, intermediate consumption and compensation of employees available for 64 industries and 16 federal states. The overall amount of each industry matches the values on national level and subtotals of federal states match aggregates from official data.

4.1.3 Trade statistics

Product-specific information on international trade is available for German federal states. Actually, there are even two official data bases, which refer to this topic, both showing certain advantages. In the following, we describe differences between trade statistics and national accounts in general and proceed with presenting the approaches used to implement the two different data bases on trade statistics into the MRHA.

In general, data on international export and import are based on the Commodity Classification for Foreign Trade Statistics (WA), which corresponds to the Combined Nomenclature (CN) and which in turn is a binding directive for all members of the EU. Both trade statistics used for the MRHA, we describe below, can be recoded to the WA classification (Destatis, 2015a). This way, we can combine information of the different statistics and use both for the compilation of the MRHA. We proceed accordingly in order to obtain the maximum of information available, so we can actually profit even more from the detailed use tables we have available from the special evaluation on national supply and use tables. Moreover, we honor the fact that resulting multiregional tables are highly sensitive to information on international exports and imports.

It is essential to note that we use trade statistics to disaggregate the national export vectors and the product-specific information on imports into 16 vectors each, representing the number of German federal states. Therefore, we do not use any absolute values of trade statistics but merely its distribution among federal states. We proceed accordingly, since trade statistics and national accounts in fact both refer to international trade but show slight differences in methodology (Destatis, 2017). In the following, we explain differences in order to point out the challenges and possible inaccuracies of international imports and exports of German federal states within the MRHA, which arise from differences in methodology.

One significant aspect is a different understanding of transferring of goods. While trade statistics record exports and imports with physical border crossing, national accounts refer to trade in accordance to a transfer of economic ownership since ESA 2010. To be more specific, in the case of bilateral contract processing, only the payment for manufacturing service is registered in national accounts, while export and import activities of the good to be processed is part of trade statistics (Destatis, 2017). There is no product-specific data available for the German federal states, which enables to conclude upon the respective amount of bilateral contract processing. Hence, we assume that the differences in methodology are product-specific and have therefore no impact on the distribution across federal states. However, we are aware that this must not apply i.e. specifically in the case of border states.

While national accounts differentiate between domestically produced and imported exports, the trade statistics in concern focus on domestically produced exports exclusively. The reverse conclusion is that imports from trade statistics do not consider re-exports, i.e. exports from imports (Braakmann, & Goldhammer, 2016). Consequently, we have to disaggregate the export vector of the import use table according to further assumptions. These re-exports make up about 18 percent of overall imports in Germany in the year 2011 (Destatis, 2015b). We disaggregate this vector in accordance to the product-specific information regarding imports for domestic use of federal states since we assume that a certain – over federal states identical – share of imports stays within the importing region and hence shows a suitable approach for disaggregation. In cases in which no imports take place for a specific good, we use output as approximation.

Another methodological difference between trade statistics and national accounts relates to the concepts of ‘special trade’ and ‘general trade’ (Eurostat, 2014). For the federal states of Germany, exports from trade statistics refer to the first, while imports refer to the latter concept just as national accounts do. Consequently, international exports of federal states lack information concerning the amount of exports, which are received into customs warehouses without subsequently entering the country of receipt. Export in terms of general trade amounted to 1,066 Bn. € opposed to 1,061 Bn. € in terms of special trade in 2011 for overall Germany (Destatis. 2016d). The difference, i.e. 5.2 Bn. € makes up around 0.5 percent of overall exports in terms of general trade. Consequently, we assume that this methodological difference does not essentially impact the relative importance of product-specific export among federal states, i.e. every federal state exports the same share into customs warehouses without having them subsequently entering the country of receipt.

Moreover, no information on imports and exports of services are available in trade statistics. With respect to the relatively small amount, which refers to this number on the national level, we disaggregate the national values with respect to regional output.

After we have explained the differences in methodology between national accounts and trade statistics and have described our approaches for disaggregation, we continue with introducing the specific trade statistics used for the MRHA.

The first trade statistic we implement into our model refers to the ‘Product Classification for Production Statistics’ (GP) (Destatis, 2016a). It shows advantages especially in its reference to production statistics and consequently national accounts in terms of classification. Based on this fact we can easily transfer this information, available for all federal states, into our model. One main disadvantage, however, shows the fact that this data is only available for 30 aggregates of goods. When we disaggregate the available information and implement it into our framework of detailed use tables it leads to the circumstance that each of the federal state shows an identical distribution of goods among subcategories of aggregates. However, we can derive adjusted distributions for each federal state by considering the second available data base on international trade. In the case of the MRHA, which lays special emphases on the health economy, this fact is of major concern. Medical technology is a part of the economy, which is not consistently shown within only one classification compared to i.e. products of the pharmaceutical industry, which refer to Classification of Products by Activity (CPA) number 21. Medical products refers to CPA 26.6 and 32.5 and is hence part of subsections of the first trade statistic in concern. Therefore, it is essential to integrate more information on this matter in order to specify differences in trade between federal states. We proceed accordingly by implementing information from the second trade statistic.

The second data base we use refers to the ‘Classification by Commodity Groups and Subgroups of the Food Industry and Trade and Industry’ (EGW) (Destatis, 2016b). It represents a traditional national classification of trade statistics. The information published arranges the goods with respect to the degree of processing. One main disadvantage of this information on international exports and imports of federal states is the fact that it does not refer to the categories of production statistics. As a consequence, it shows a classification very unlike to the one used in national accounts. Its major advantage, however, is the amount of available information on 211 categories. To use the example described above, one of these categories directly refers to medical products.

Consequently, we recode the EGW statistics to make it suitable the categorization of national accounts. This way we link both data bases. In order to recode the EGW statistics to the GP statistics, we need a recoding table. Unfortunately, no such table is available, establishing a direct link. However, recoding tables for both statistics are available in order to reconcile with the WA statistics mentioned before. We are hence able to merge data following a two-step procedure. We transfer international trade from the EGW statistics into the WA classification in a first step and reconcile the obtained data with the GP classification in a second step.

In order to implement this data into our model we proceed as follows. Trade from the GP classification still is our superior data base, as it represents a direct link to the categories of national accounts. Data from EGW statistics consist of information mostly reflecting very specific characteristics, representing only similarities to the product in concern from national accounts; one could also call it the 'closest reference value'. Consequently, we disaggregate the export vector from the domestic use table with respect to the distribution of the GP statistics among federal states in a first step.

In a second step we implement data from the EGW data base. When matching this data we obtain a situation similar to the one shown as an example in column three and four of Table 1. Some goods of the nine-digits-level of GP match more than one EGW category. Conversely, one EGW category matches more than one GP category. The main goal is to implement as much information as possible by keeping in mind that we do not implement the absolute values of data on export and import but their relative distribution over federal states in order to reach the national value.

Table 1: Matching of GP and EGW classifications on international trade

Export	Import	EGW	GP	Aggregates
a	y	101	014310000	014310000
b	v	109	014310000	014
c	w	102	014110000	014
c	w	102	014211000	014
c	w	102	014212000	014
d	x	103	014610000	014610000
e	y	105	014511000	014511000
b	v	109	014512000	014
f	z	107	014711000	01471
f	z	107	014712000	01471
f	z	107	014714000	01471
f	z	107	014713000	01471
b	v	109	014919000	014
b	v	109	030069000	030069000
b	v	109	014911000	014
b	v	109	014913000	014
b	v	109	014912000	014

Source: Own calculations.

Within the following procedure we evaluate the highest common GP-denominator in order to eliminate double entries within the EGW statistics. We start at the three-digit-level and leave the one- or two-digit-level unconsidered, as the GP trade statistics is our superior data base, referring to the two-digits-level. For example, EGW 109 refers to GP categories 014310000, 014512000, 014919999, 030069000, 0149110000, 014913000 and 014912000. The highest common GP-denominator among GP categories at the three-digits-level is 014 on the one hand and 030069000 on the other hand.

At this point we are able to aggregate the volumes of the respective exports and imports leaving out double entries of EGW information. Within the next steps we proceed stepwise. We start with aggregates consistently reconciling to a three-digits-level and apply the federal state distribution on the national values. Within the further procedure we apply more information concerning the four- to eight-digits-level on the available data with respect to available information. Within the final step, we apply the distribution of the available nine-digits-level over data in cases there is information available. In cases two or more different EGW classifications refer to the same GP classification we aggregate them in order to get a ‘best guess’ concerning the distribution of exports and imports over federal states.

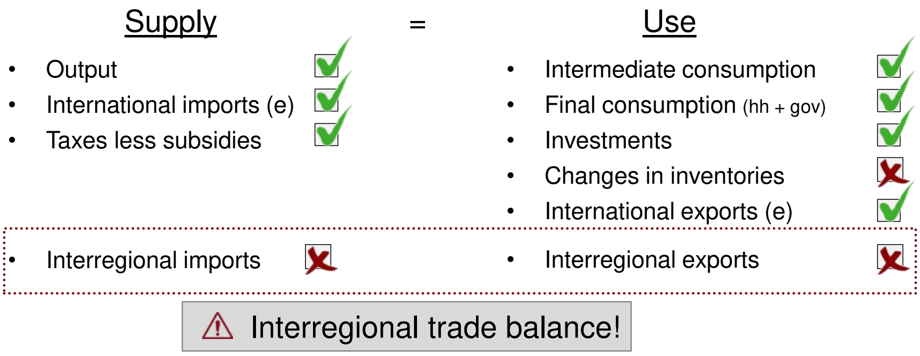
Resulting estimates concerning the distribution of national trade from domestic production are reconciled within the next step by applying the GRAS algorithm on subsections of the resulting matrix. Row sums refer to values of the national table, whereas the column sums in concern refer to the amounts of trade from the very first estimate resulting from pure GP data on each of the two-digits-level. This way we use superior data to define to volume of imports and exports on the two digits level, but obtain a variation of specialization within the three- to nine-digits level as we have implemented information from the EGW data base.

One special situation occurs during the procedure. Trade statistics refer to purchasers’ prices while the use table on hand refers to basic prices. In turn, this means we asserted i.e. exports at basic prices according to information on trade at purchasers’ prices. Consequently, we only distributed a part of trade statistics across federal states up until now. Hence, there is a positive gap between the overall amount of the trade statistic and the already distributed exports at basic prices for each federal state. We assume this gap refers to trade margins. Consequently, we distribute the national value of export trade margins according to federal-state-specific gaps.

4.1.4 Changes in inventories and amount of interregional trade

National accounts represent one consistent framework, in which the amount of goods and services supplied – produced and imported – equals the amount of goods and services used – within the country considered and exported to other countries. We have information on output from regional accounts - derived from information on GVA and intermediate consumption - and estimated the amount of international imports in the previous subsection. Consequently, the only information missing on the supply side is imports from other federal states. On the use side, we have information on intermediate consumption, final consumption of households and governments, investments and estimated international exports. Therefore, information missing on the use side represents changes in inventories and the amount of exports to other federal states.

Figure 5: Available and missing data



Source: Own illustration.

Given the situation we knew about changes in inventories, we would be able to tell the interregional trade balance of each federal state. On the national level, changes in inventories represent about 0.2 percent of overall use, ignoring the amount changes in inventories itself. As this number is very little, we decided to apply this share to the already calculated amount of use for each of the federal states. The difference between supply and use, now calculated changes in inventories included, results in the interregional trade balance depicted in Table 2.

Table 2: Calculated interregional trade balances and data on international trade balances for 2011

	interregional trade balance (MRHA)*	internationale trade balance (Destatis, GP classification)**	total trade balance
Baden-Württemberg	-13,000	28,501	15,501
Bavaria	-6,000	14,339	8,339
Berlin	5,000	2,748	7,748
Brandenburg	-8,000	-4,617	-12,617
Bremen	3,000	1,245	4,245
Hamburg	37,000	-27,819	9,181
Hesse	42,000	-21,387	20,613
Mecklenburg Western Pomerania	-12,000	2,718	-9,282
Lower Saxony	-10,000	-7,854	-17,854
North Rhine-Westphalia	52,000	-27,682	24,318
Rhineland Palatinate	-24,000	13,345	-10,655
Saarland	-1,000	1,821	821
Saxony	-28,000	9,155	-18,845
Saxony-Anhalt	-9,000	-170	-9,170
Schleswig-Holstein	-12,000	-2,668	-14,668
Thuringia	-14,000	4,624	-9,376

Source: Own calculations, Destatis (2016b); *deviations from zero of the overall sum due to rounding; **calculation of the trade balance from official trade statistics on German federal states is methodologically incorrect, as exports refer to the concept of 'special trade', while imports refer to 'general trade' (see page 18 for more details). In order to get a rough feeling of the amount, however, the difference of international exports and imports is shown nevertheless.

We do not explicitly add this information on interregional trade to our model. Moreover, it represents the remaining amount of products and services of federal states, which they lack or have in advance and therefore start trading with the other federal states. Consequently, by allowing interregional trade, the restriction of supply equaling use can be fulfilled. The iterative algorithm hence independently applies the trade balances for each of the federal states as a necessary condition to be met.

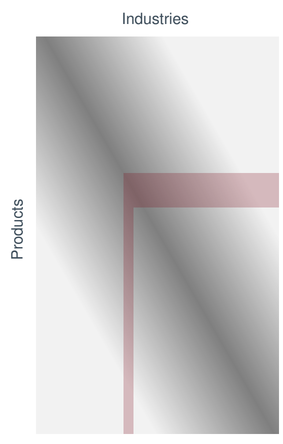
4.1.5 Employees subject to social security contribution

Data on employees subject to social security contribution are available for German federal states at the three-digit level, hence providing information for 272 industries each (BA, 2011). This information is of high informational content in the case of the special evaluation on supply and use we are working with. This way, we can use this data to implement some characteristics of federal states into the initial tables already one step before the algorithm is applied onto it.

We discuss the preparation of the initial table in subsection 4.2 in detail. In order to understand the following procedure it is however useful to be aware of the fact that we start with multiple national supply and use tables arranged within one initial multiregional supply and use table. This initial supply and use tables are subsequently adjusted when the iterative algorithm is applied. In contrast to starting with 16 identical national supply tables, we now adjust those in advance by incorporating information on employees subject to social security contribution and apply the information gathered on the domestic use tables as well.

Before we describe this procedure we set an example in order to facilitate a better understanding of the approach. Products of medical technology refer to CPA 26.6 and 32.5. Hence, it is a primary product of industry aggregates NACE 26 “Computer, electronic and optical products” and NACE 31-32 “Furniture; other manufacturing goods” for which we have information on GVA, output and employment. As the names of industries suggest, the mentioned indicators refer to many more products of primary production than just medical technology. Hence, we want to add some regional characteristics on the product side of the ‘to-be-adjusted’ supply tables for the 16 federal states. This way, we honor information we have on federal state specialization (in terms of employees subject to social security contribution) within the industry aggregate at the two-digit level (i.e. 26 and 31-32) and apply this regional-specific distribution among the product side of the subcategories of aggregates. To be more concrete, this means a regional-specific distribution of output among the subcategories of i.e. CPA 26 “Computer, electronic and optical products” in accordance with information we have on employees subject to social security contribution instead of the national distribution. This information refers to eight subcategories of NACE 26, from 26.1 to 26.8. We do not concentrate on medical technology exclusively but apply this procedure on the overall table.

Figure 6: Imbalance between industry- and product-specific information in the supply table



Source: Own illustration.

At this point it is essential to note that the sums of product aggregates at the two-digit level of each supply table remain consistent with the national table. We only adjust the subcategories of aggregates in their composition with respect to the information on employees subject to social security contribution.

The rectangular dimension of the special evaluation of supply and use tables is responsible for carrying out this adjustment. On the one hand, it is of high value for our model to have such detailed information on the product side of supply and use tables. On the other hand, however, for each federal state, available data on output for 64 industries is supposed to simulate product information of around 900 categories. This results in an imbalance between given and desired information we try to represent in Figure 6. Hence, it is likely the algorithm fails to implement certain characteristics on the product side that are not reflected by the given information on the industry side. This is the rationale to adjust subcategories of two-digits-level aggregates in accordance to information on employees subject to social security contribution. This way, we obtain 16 different supply tables in terms of specialization at the subcategories of the two-digit level.

We are well aware of the fact that we mix up information from the industry side with the product side by following this procedure. However, since information on structures of federal states are seldom at this level of detail we decided to ignore the fact of secondary production of industries and assume that a specialization of employment in a certain industry leads to a specialization of the corresponding production of goods or services. At this point we stress the fact that this procedure only puts regional characters into the model without further assumptions such as assuming any fixed numbers.

4.1.6 Health expenditure

One essential step of calculating the NHA and consequently the MRHA it to match household and government final demand with data from the health expenditure survey. The latter serves as a secondary data base, which provides information on expenditures for a better health status of the inhabitants. By matching both data bases, we obtain the core part of the health economy in terms of definition and quantification. At the national level, official data on health expenditure is available by categories of providers, function and financing. For the compilation of the MRHA, our colleagues from BASYS extended these national figures by a regional component.

Our colleagues conducted the calculations with respect to the concepts of national accounts, therefore referring to the domestic concept of health expenditures. This differs from the health expenditure survey provided by the Federal Statistical Office at the national level. The latter corresponds to the resident concept, consequently referring to health expenditures of German citizens only. The same overall amount of expenditures applies to the regional health expenditure survey our colleagues calculated. However, the difference lies in the treatment of patient migration among federal states. The resident concept registers expenses at the place of the patient's residence, while the domestic concepts asserts expenditures to the place of treatment. The latter applies for the MRHA, since expenditures at the place of treatment correspond the output of the respective federal state. Consequently, output of patient treatment is always recorded at the place of treatment, not at the place of the patient's residency. Hence, patient migration cannot be observed as import and export in the MRHA.

Categories of the health expenditure survey refer to inpatient treatment, outpatient treatment, medication, medical products and administrative expenditures of health insurance companies. This information is necessary in order to extract the health economy from the overall economy and hence calculate a satellite account from national and multiregional accounts. During the compilation of the NHA, matching of expenditures with final consumption of households and the government reveals some deviations of German national accounts from the health expenditure survey when there should be none. This is due to some differences in concepts, which are described in more detail in Schwärzler & Kronenberg (2016). However, deviations also arise due to inaccuracies of national accounts. To some point, this is justifiable since national accounts focus on the overall economy whereas the health expenditure survey evaluates more accurate information on its specific field. Conversely, it means we should implement data on health expenditures already at this point of compiling the MRHA in order to improve the quality of the multiregional supply and use tables. Hence, we use information from the regional health expenditure survey to distribute national values among federal states. By doing so, some additional assumptions have to be made, which are discussed within the next paragraphs.

Expenditures on inpatient and outpatient treatment as well as on administration of health insurance companies directly refer to domestic output of respective federal states. This is due to the domestic concept applicable to both regional accounts and regional health expenditures. Hence, we use the respective information from the regional health expenditure survey in order to distribute the corresponding values of the national use table among federal states.

Obviously, this assumption does not hold for medication and medical products as they show international and interregional export and import dynamics in contrast to inpatient and outpatient treatment. In this context, we assume perfect heterogeneity of the products in concern and hence argue there is no preference for regionally manufactured products. Moreover, transport costs are irrelevant in decision making. There are several reasons, which support these assumptions.

First of all, the kind of disease a patient suffers from is the greatest influencing factor on the sort of medication he or she receives. In this context, we assume an identical distribution of diseases patients suffer from across federal states. Hence, it is always x percent of patients, who suffer from cancer and y percent of patients, who suffer from cardiovascular disease in each of the federal states and so on. This implies an identical distribution of the need for the specific kind of medication, which treats the disease in concern.

Second, manufacturers of medication and medical products usually only have one site for the production of a certain kind of medication within a larger area, due to a high specificity of the manufacturing process. For example, the company Bayer AG produces the medication Aspirin at a site in Saxony-Anhalt. This site is one of the most important locations for the production of Aspirin worldwide (Bayer AG, 2015). There are other painkillers, which are produced in Germany, however. Yet, Aspirin is only produced in Saxony-Anhalt.

Third, the decision upon the kind of i.e. painkiller a patient consumes, does usually not depend on regional origin. Much more, it is a question of ingredients and patient's tolerability. Apart from that, around 87 percent of medication obtained from the pharmacy refers to prescription drugs (BAH, 2016). In the case the doctor prescribed only the name of an active ingredient for treatment or does not specifically exclude replacement of the prescribed medication by another one, the so-called 'aut-idem ruling' applies (SGB V,

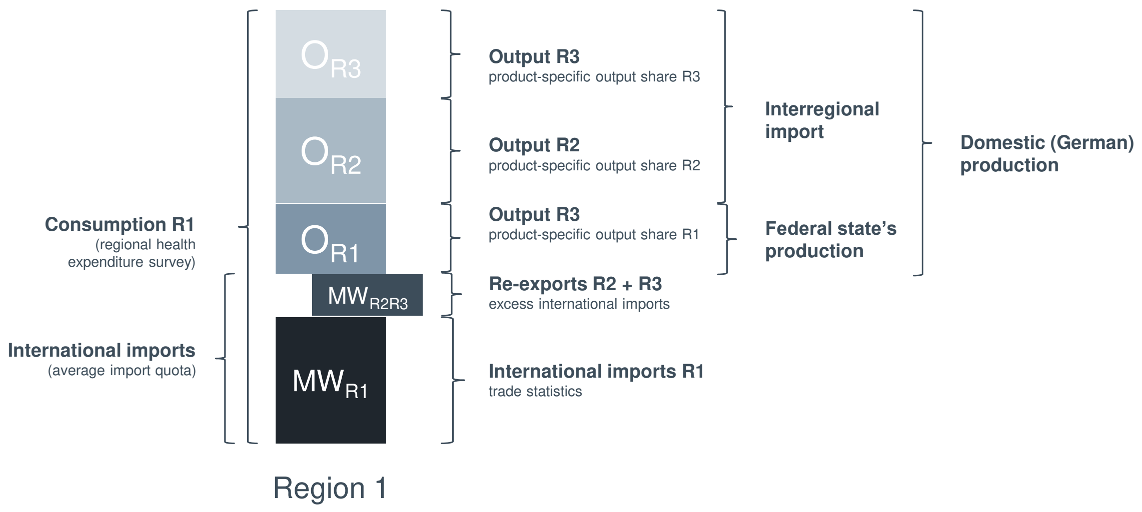
§129). This obligates the pharmacy to hand over the cheapest available alternative medicine showing consistency in terms of ingredients, dosage form and package size. In the case a rebate contract exists between statutory health insurance funds and the manufacturer of the product for a suitable medication, the pharmacy is obligated to hand over no other than this medication (SGB V, §130a).

We hence argue that the assumption of perfect heterogeneity of products and irrelevance of transportation costs is given. Each site produces a completely individual medication in terms of ingredients, price and the existence of rebate contracts. This mixture of different health products manufactured distributes across all over Germany. However, the perfect solution would be to match production sites with data on prescribed drugs in order to evaluate interregional trade. This is not possible due to unavailability of data.

In order to introduce interregional trade of health products, we hence implement the assumption on perfect heterogeneity into our model. We distribute the national amount of international imports over federal states first and quantify the amount of interregional imports in a second step.

In a first step, we assume that each federal state obtains the same share of health expenditures from imports of the product in consideration (i.e. medication or medical products). Hence, we use federal-state-specific health expenditures on the product in consideration to distribute the corresponding national value of imports across federal states. We refer to this amount with 'International imports (average import quota)' in Figure 7. This amount is fixed over all iterations of the algorithm. As illustrated in Figure 7, this value does not necessarily need to equal the specific amount of imports obtained from the trade statistic. We refer to the latter with 'International imports R1 (trade statistics)' in Figure 7. This means we have excess or shortage of imports within each federal state. In the case illustrated in Figure 7, when a federal state shows a shortage of international imports from trade statistics opposed by the just calculated amount of health expenditures from imports, the corresponding missing amount is recorded as re-export from another federal state. We refer to this value with 'Re-exports R2 + R3 (excess international imports)' in Figure 7. The other federal state in turn is of import excess given its amount of imports from trade statistics opposed by health expenditures multiplied with the average import quota. This interrelationship between federal states can be obtained from Figure 8.

Figure 7: Assumptions on the origins of health goods for region 1

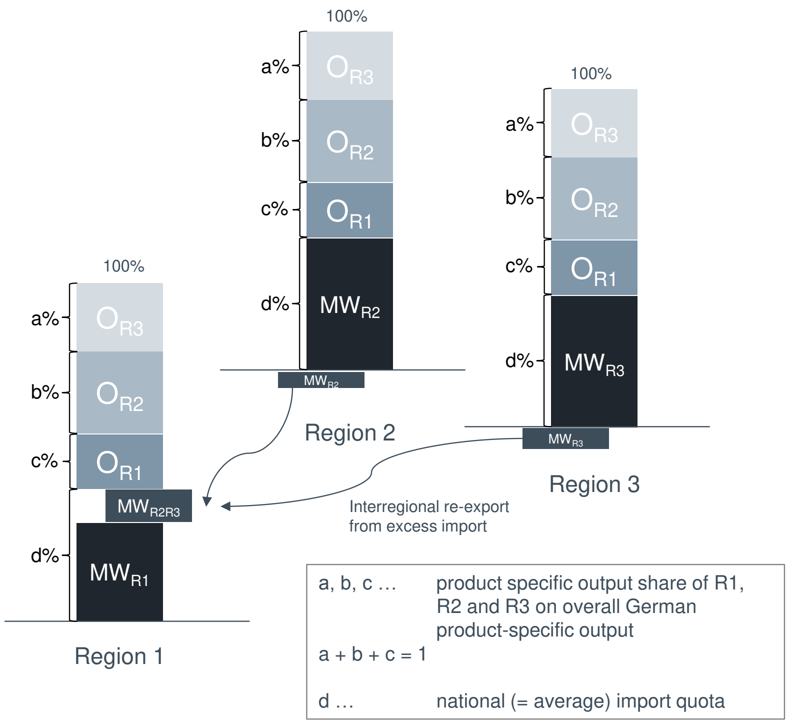


Source: Own illustration.

Due to the assumption of perfectly heterogeneous goods, each federal state obtains a mixture of medication and medical products from all federal states with respect to the amount of the product-sided output manufactured within each of the federal states. For example, federal state 1 supplies 30 percent of overall German output of medicine. Therefore, each federal state obtains 30 percent of its domestic demand from federal state 1. As the algorithm used to obtain the MRHA is of an iterative kind, product-specific output shares change within each stage of calculation.

This situation of interregional dependency in the case of manufactured health products is shown in Figure 8. Health products obtained within each region comprise of the exact equal share of interregional imports and moreover the exact equal share of involvement of each federal state.

Figure 8: Assumptions on the origins of health products in region 1, region 2 and region 3



Source: Own illustration.

At the end of this procedure we obtain fixed values for the consumption of manufactured health products, which all refer to the categories of private and public consumption in use tables. However, these fixed values change with each iteration of the algorithm. Table 3 shows a numerical example of the just described procedure.

Table 3: Numerical example on the assumption of origins of manufactured health products.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	Overall Health Expenditure	**Import quota**	**International imports**	**domestic health expenditures**	**Output**	**Output share**	**Supply R1**	**Supply R2**	**Supply R3**	**Sum**
			*(C1 * C2)*	*(C1-C3)*	*iteratively changing*	*iteratively changing*	*(C4 * C6[R1])*	*(C4 * C6*	*(C4 * C6[R3])*	*(C7 + C8 + C9) = C4*
R1	35	0.3	10.5	24.5	70	35%	8.575	3.675	12.25	24.5
R2	10	0.3	3	7	30	15%	2.45	1.05	3.5	7
R3	55	0.3	16.5	38.5	100	50%	13.475	5.775	19.25	38.5
Germany (given data)	**100**	**0.3**	**30**	**70**	**200**	**100%**				

Source: Own illustration.

4.2 Alignment of the initial matrix

In subsection 4.1 we describe the preparation of primary and secondary data for the MRHA. In this subsection we focus on the alignment of the initial matrix, in advance to applying the iterative algorithm on the overall concept elaborated within the preceding and this subsection. In order to compile the initial matrix a few additional assumptions and manipulations have to be conducted. Those consist of the general arrangement of matrices for the multiregional framework and the handling of given data, such as the ones derived within the previous subsection.

In a first step, we establish the multiregional framework according to Figure 1 and Figure 2, but for the 16 federal states of Germany, therefore replacing three by 16 regions. At the beginning, all matrices involved in the multiregional table are consistent with national tables, therefore picturing the German overall economy each. In accordance to sub-subsection 4.1.5, however, the supply tables are adjusted with respect to additional information in order to take into account the imbalance between industry information and the number of product categories referring to it. Use tables are adjusted accordingly in order to keep tables balanced with regard to supply and use.

Tables also need to fulfill the requirement that the sum of the initial matrix equals the overall amount of the final matrix. Hence, the 16 supply or 16x16 use tables are downgraded so they correspond to the amount of the overall German economy.

The next step concentrates on the setting of use tables. Imagine, we assign the same use matrix to each of the off-block-diagonal elements and the block-diagonal elements, the first referring to interregional trade, the latter to own domestic use of the federal state of concern. This setting would suggest that there are no transportation costs within the German economy nor there are other restrictions such as preferences for regional goods. From a methodological perspective, the algorithm registers only equal values among use tables and hence captures no preferences among interregional trade or domestic use. Unequal values indicate there is a preference among interregional trade and domestic use, i.e. reducing the amount traded due to transportation costs.

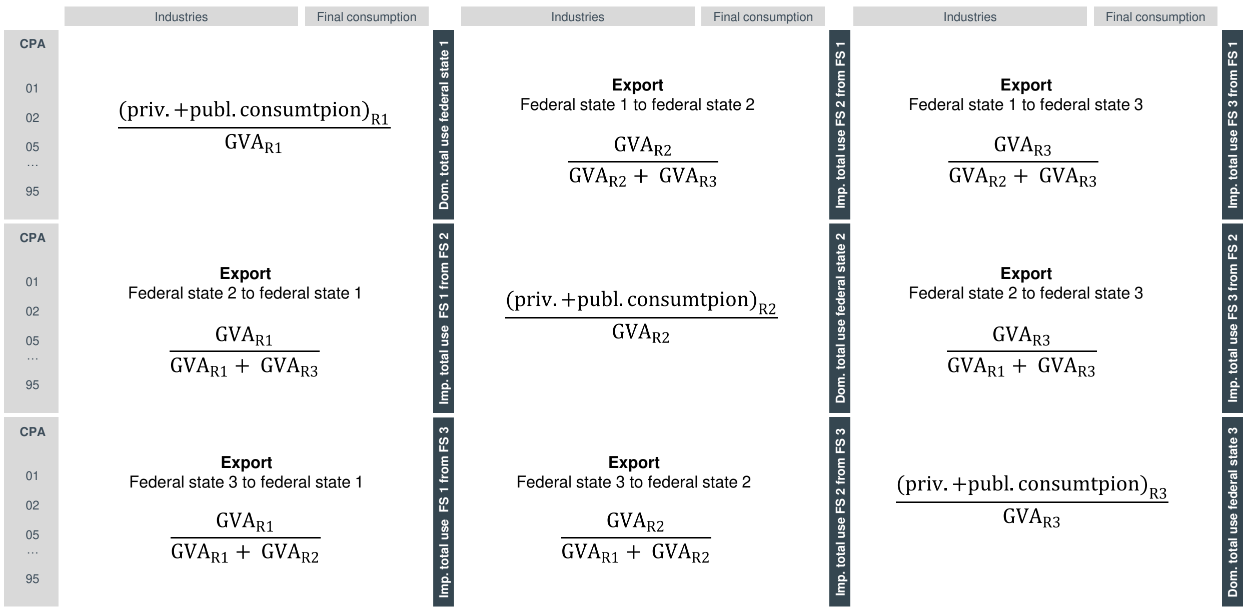
The way initial matrices for interregional trade are weighted thus impacts on the degree of openness of federal states. As we have fixed values for the interregional trade balance of federal states it causes changes in the amount of cross-hauling, i.e. the simultaneous export and import of goods and therefore the assumed heterogeneity of goods. Hence, we have to find a reasonable initial matrix, which takes into account a realistic ‘openness of the federal state’ towards interregional trade.

In order to proceed accordingly we define the openness of each federal state by the ratio of overall public and private consumption to GVA. Both of the two indicators used relate to the federal state in consideration. The first refers to overall regional demand for consumption expenditures to be satisfied, while the latter refers to the regional value added caused by the supply of products. This way we can approach differences of federal states in their capability of supplying regional demand as we calculate the deviation from the average value of this indicator for each federal state. We apply these 16 values to the diagonal elements of a 16x16 weighting matrix, each cell referring to exactly one federal state or the respective interregional trade.

In a next step, we concentrate on the direction of openness in terms of interregional export, hence the off-diagonal elements of the 16x16 weighting matrix. We only have to define one side - interregional exports or interregional imports - as the distribution of one of the directions of trade leads to the other.

One possible solution to this is to apply spatial interaction models.Többen & Kronenberg (2015) discuss and summarize different approaches. Over here, we assume that the exporting federal state distributes its products among the other regions with respect to the purchasing power of recipients. Hence, we calculate the share on overall GVA of each federal state in 16 variations, each time omitting the federal state which is represented in the diagonal element. This way, we can approach a first guess on the distribution of destinations for interregional exports for each federal state. We insert these values into the off-diagonal elements of the 16x16 weighting matrix. Within a final step, we rescale this matrix to one so that the national domestic use table, available 16x16 in the initial framework, multiplied by the weighting matrix, equals to the overall amount of the national domestic use table.

Figure 9: Weights for the initial matrix on domestic (German) use.



Source: Own illustration.

We multiply supply tables accordingly by assigning row sums of the weighting matrix, as the concept of interregional trade does not apply to the supply tables. The only reason for the weighting of supply tables is that supply and use tables are balanced again. It has no further impact on the supply tables since output of industries, which is going to be assigned within the iterative algorithm, adjusts the overall amount of supply tables immediately.

As there is a possibility of interregional re-exports of international imports, we have to apply a similar procedure on the initial matrix of the national import use table. We do not have any information or approaches to calculate the individual openness for re-exports of federal states, hence we apply the national share of non-re-exports on overall imports to the diagonal elements of the import weighting matrix. Consequently, each federal state has the same – national – propensity for re-exports. The direction of re-exports is evaluated again in consideration of GVA ratios of the destination federal states. The final weighting matrix is aligned to one in the end and applied on the 16x16 framework of national import use tables.

At this point it is essential to note that preceding steps, which involve the alignment of the initial matrix according to the openness for interregional trade of federal states, do not imply any fixed values of the final matrices. The initial matrix is only a general setting, which is adjusted within the algorithm afterwards. There are no binding restrictions, so that the amounts of interregional trade still adjust iteratively.

In a next step we eliminate entries within matrices where we have fixed values such as international exports or private and public consumption on health care goods and services. Experience has also shown that it is essential to make restrictions upon changes in inventories too, as they consist of positive and negative entries and make up substantial amounts of some product groups at the detailed level we are working with. Consequently, we restrict changes in inventories to the place of production. Moreover, we distribute the national value among federal states in accordance to the ratio of exports to changes of inventories at the national level. This only applies in cases the latter has significant importance on the overall value of the product group in consideration. In cases changes in inventories only have a low impact on the product output, the distribution of changes in inventories among federal states is adjusted with each iteration in accordance to the distribution of product output among federal states. Consequently, we now also have fixed values for changes in inventories and set respective values within the initial multiregional matrix to zero.

Furthermore, we restrict interregional trade on some services, involving administration, education, health services, social work activities, services concerning sports, entertainment and recovery, other personal services and private households with employed persons. We proceed accordingly due to the domestic concept those services apply to. This means we ignore the existence of online training in the context of tertiary education or telemedicine in the case of health care due to their very rare occurrence to the current point of time.

4.3 Basic concept of the SUT-RAS algorithm

The SUT-RAS algorithm (Temurshoev & Timmer, 2011) intends to project supply and use tables in an iterative and mutually dependent matter with respect to information on the industry side and sums of final consumption categories. Hence, there is no urgent need for product-specific information in order to project tables. This circumstance constitutes a major difference to related iterative algorithms such as RAS.

At the national level, we use the SUT-RAS algorithm exactly with its initial intention, which is to project available national tables on supply and use. We proceed accordingly, so we are able to quantify the economic impact of the health economy also apart from the years the generic national supply and use tables refer to. This is important, as tables are only available for a number of years at the current statistical standard of NACE 2008 and ESA 2010. We describe the underlying data base and the algorithm applied for the national case in detail in Schwärzler & Kronenberg, 2016.

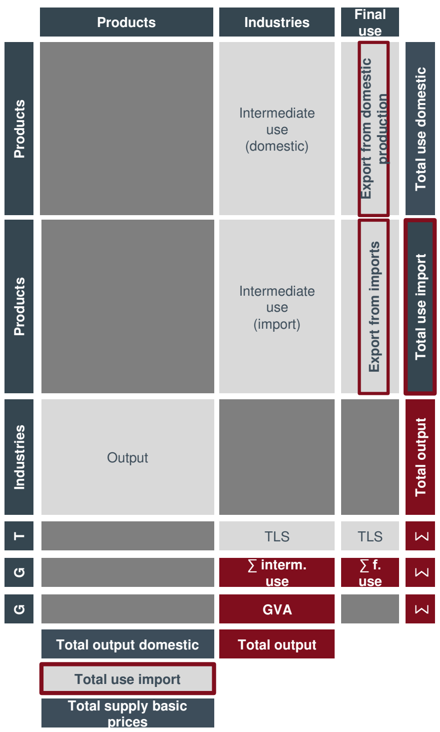
Since this paper focusses on the further development of the SUT-RAS algorithm into the MR-SUT-RAS algorithm, we present the main underlying formulas over here as well. The intention is to provide a broad picture and facilitate a better understanding regarding developing the MRHA.

At this point we want to emphasize that there are several ways to apply the SUT-RAS algorithm in general. The choice of procedure depends on the available data set of supply and use tables. It is possible to project tables at purchasers or at basic prices, applying the algorithm on domestic and import use tables separately or on the overall sum of the two tables. Moreover, it offers the possibility to include additional specific information on either the supply or the use side.

Within the next few paragraphs we present the formulas of the SUT-RAS, which correspond to the setting of basic prices and separated use tables. This reflects the requirements that are met by the special evaluation on supply and use tables from national accounts. Moreover, we expand this setting due to available information on product-specific export and import data. Hence, the provided formulas do not refer to Temurshoev & Timmer (2011) exactly, as no section focusses precisely on the setting available in this case. In fact, it is a combination of different situations evaluated in Temurshoev & Timmer (2011).

As already mentioned, information on industries and final use categories are prerequisites for the projection of supply and use tables in accordance to the SUT-RAS algorithm. Moreover, the minimum of information we need in our case in addition is the overall sum of imports and taxes less subsidies. Those critical areas of data supply refer to the red colored areas in Figure 10. In formula notation, industry output refers to vector $\bar{x}$, while vector $\bar{u}$ indicates total use and therefore the individual sums of intermediate and final use.

Figure 10: Data requirements for the SUT-RAS algorithm



Source: Own illustration.

Additional information on i.e. exports and imports can be implemented to increase the validity of projected tables. Those areas show a red frame in Figure 10. Product information on imports are denoted by $\overline{mt}$, with respective information on re-exports already subtracted. Product information on exports from domestic production refer to certain cells of the use table, while their appearance among industries in the supply table is not known. Hence, additional information we have on the use side are denoted by vector $(-f)$. Referring cells in the use table are set to zero. Vector $(-f)$ consequently indicates the resulting difference in sums over products of the supply and the domestic use table. Consequently, final supply and use tables are balanced the moment we insert the information on exports into the target cells of final tables, due to having considered the difference along the iterative algorithm.

Note at this point, that the respective information has to be subtracted from the vector $\bar{u}$ as well, as it contains information on the final value of overall exports as well. In the case the overall amount of exports comes from secondary data and is hence manually set, not only the overall respective vectors in both use tables have to be set to zero, but also to be completely removed, as a vector of purely zeroes cannot be applied within the algorithm.

N_0^v and P_0^v denote the initial and hence the to be projected supply table, which is separated into a negative and positive matrix, both showing the corresponding entries in absolute positive values. The same procedure is applied on the domestic use table, indicated by N_0^d and P_0^d, and on the use tables of imported products with the corresponding notation N_0^m and P_0^m. Vector m_0 indicates overall product-specific imports of the initial import use table.

The SUT-RAS algorithm is applied iteratively, focusing on four interdependent adjusting vectors. The vectors r_d and r_m adjust the initial matrices of use tables at the product side. Vectors s_u and r_v are applied at the industry side.

To be more specific, vector r_d assures balancing conditions of the supply table and domestic use table. In order to include given information on i.e. domestic exports, r_d considers the vector $(-f)$ as an authorized difference between supply and use table during the compilation.

$$r_d = 0.5 * \widehat{p_d}^{-1}(f + \sqrt{f \circ f + 4 * p_d \circ n_d}) \tag{1}$$

where

$$p_d = P_0^d s_u + N_0^{v\prime} \hat{r}_v^{-1} i \tag{2}$$

$$n_d = N_0^d \widehat{s_u}^{-1} i + P_0^{v\prime} r_v \ . \tag{3}$$

The vector r_m is applied on the initial matrix of the import use table in order to obtain consistency with given product-specific data on imports, denoted by vector $\overline{mt}$. Note that this vector includes information on the overall sum of taxes less subsidies in the very last element. This one corresponds to the final row of the initial import use table, reflecting information on taxes less subsidies among industries and final consumption categories.

$$r_m = \sqrt{\widehat{P_0^m s_u}^{-1} (\widehat{N_0^m \hat{s}_u^{-1}} \iota + rm_0)} \tag{4}$$

where

$$r = \overline{mt}/(m'_0\hat{r}_m^{-1}i)\ . \qquad (5)$$

On the industry side, s_u is applied on the initial matrices of domestic and import use tables in order to reflect given industry-specific data on intermediary and final use, denoted by vector $\bar{u}$.

$$s_u = 0.5 * \widehat{p_s}^{-1}(\bar{u} + \sqrt{\bar{u} \circ \bar{u} + 4 * p_s \circ n_s}) \qquad (6)$$

where

$$p_s = P_0^{d\prime} r_d + P_0^{m\prime} r_m \qquad (7)$$

$$n_s = N_0^{d\prime} \widehat{r_d}^{-1} i + N_0^{m\prime} r_m{}^{-1} i\ . \qquad (8)$$

Vector r_v adjusts the supply table to given output of industries, denoted by $\bar{x}$.

$$r_v = 0.5 * P_0^v \widehat{\hat{r}_d^{-1} i}^{-1} \left(\bar{x} + \sqrt{\bar{x} \circ \bar{x} + 4 * (P_0^v \hat{r}_d^{-1} i) \circ (N_0^v r_d)}\right) \qquad (9)$$

The iterative algorithm stops as soon as changes in r_d and r_m correspond to a specific chosen level of tolerance. The four major adjustment vectors obtain projected supply and use tables by performing the following procedure on initial matrices:

$$\bar{V} = \hat{r}_v P_0^v \hat{r}_d{}^{-1} - \hat{r}_v^{-1} N_0^v \widehat{r_d} \qquad (10)$$

$$\bar{U}_d = \hat{r}_d P_0^d \hat{s}_u - \hat{r}_d^{-1} N_0^d \widehat{s_u}^{-1} \qquad (11)$$

$$\bar{U}_m = \hat{r}_m P_0^m \hat{s}_u - \hat{r}_m^{-1} N_0^m \widehat{s_u}^{-1} \qquad (12)$$

In a very last step, product-specific fixed data, i.e. domestic exports and re-exports, are assigned to the projected tables. Final tables correspond to given data on industry output and intermediate use, are balanced between supply and domestic use, include fixed values on i.e. exports and match given data on product-specific import.

The result of this procedure is projected national tables. Hence, the described formulas correspond to the generic intention of the SUT-RAS algorithm according to a specific case of Temurshoev & Timmer (2011), which is basic prices, separation of domestic and import use tables and given information on product-specific exports and imports. We derive from this point in order to further develop the just described procedure into a multiregional framework.

4.4 The MR-SUT-RAS

In this section, we depict the adjustments we made to the SUT-RAS algorithm in order to apply it for the multiregional context. We hence take knowledge upon the generic formulas from subsection 4.3 as given.

One of the major advantages of the SUT-RAS algorithm is that no information on the product-side is necessary in order to adjust an initial matrix to new information on industries and final use. However, in a multiregional context we do not just update an initial matrix to unknown product-specific information. Yet, we know that the sum of each specific product, available once in each of the 16 federal states, has to equal the national value.

Consequently, this is the most essential additional restriction of the MR-SUT-RAS, since it assures the multiregional table to correspond to product-specific national values in addition to industry-specific national values. The latter restriction is easily implemented and not further discussed, since industry-specific information is directly assigned to the algorithm, in accordance to the original SUT-RAS algorithm.

The second important adjustment refers to iteratively changing fixed values concerning health product consumption (see sub-sub-section 4.1.6 for more details) and changes in inventories (see end of subsection 4.2 for more details).

Over here we want to mention that some adjustments to the original formulas lead to a number of further adaptations and restrictions. This becomes important especially in the case of fixed values concerning changes in inventories. The special evaluation on supply and use tables at hand plays a decisive role in this matter. Sometimes, detailed data lack accuracy. In our case, doubtful data refers to high ratios of changes in inventories on remaining categories of demand for relatively unspecific data (i.e. 'other products of …'). This encourages the assumption that these categories meet compensatory requirements of tables. Product output equal to zero, due to changes in inventories and the remaining categories of use leveling each other out, are another example of critical data. Hence, the more information we implement on product-specific data, the more we have to cope with probably unreliable data. This is why we will add some extensions on 'further restrictions' to our adjustments below. Those take care of certain circumstances, which might appear during the computation due to special cases in the characteristic of some product groups.

After we gave a first introduction on additional adjustments and challenges concerning the MR-SUT-RAS we proceed with the concrete steps of compilation. In order to do so, we refer to the formulas in subsection 4.3 and add our adjustments to the formula in consideration including a reference in lowercase letters.

In order to apply the MR-SUT-RAS we start with (2) and (3). Before we calculate the vector r_d,according to (1), which balances supply and use in consideration of fixed values represented by $(-f)$, we compute the latter first.

In sub-subsection 4.1.6 we explain the reasons for applying this procedure on health care products. Summarized, we have information on regional health products consumption. However, we do not know the federal state of origin of the consumed products and respective interregional trade. Hence, we assume perfect heterogeneity of medication and medical products. In practice, this means people and health facilities spare no expenses on the appropriate health product in terms of transportation costs. Moreover, they show no preference for regional products. Therefore, we distribute the origins of consumed products with respect to output share of federal states. Consequently, each federal state obtains the same mixture of health products in terms of their origins. Due to the iterative calculations, the product-specific output and hence its distribution among federal states adapts with each round. This is why we do not obtain constant fixed values for the interregional trade of health care products.

We obtain the distribution of product-specific output from the current supply table, subscript k referring to its iterative character, by applying (10):

$$\bar{V}_{k} = \hat{r}_v P_0^v \hat{r}_d^{\,-1} - \hat{r}_v^{-1} N_0^v \widehat{r_d} \tag{3a}$$

Vector $\bar{v}_{k_i}$ refers to the product-specific output:

$$\bar{v}_{k_i} = \sum_{j=1}^{j=b*64} \bar{v}_{k_{ij}} \tag{3b}$$

Hence, for $\bar{v}_{N_i}$ indicating the replicated national product-specific output, defined as a b x n X 1 vector, where n is the amount of products categories within the overall economy and b refers to the number of regions, we obtain the product-specific output share $\widetilde{\bar{v}_{k_i}}$ of federal states by

$$\widetilde{\bar{v}_{k_i}} = \frac{\bar{v}_{k_i}}{\bar{v}_{N_i}} \tag{3c}$$

We now distribute the health expenditures on products of federal states among regions in order to model interregional trade. Overall health expenditures are denoted by matrix E in the dimension of n X b x 3, the number ‘three’ indicating the categories of final consumption essential in this matter – households, non-profit organizations serving households and governments. Product categories refer to n in dimension, but all elements not corresponding to health products of concern being set to zero. In order to apply output shares on the expenditure of federal states, we expand E to $\tilde{E}$, the b-fold health expenditure matrix with the dimension n x b X b x 3:

$$\tilde{E} = \begin{matrix} E \\ \dots \\ E \end{matrix} \tag{3d}$$

We now obtain adjusted health expenditure of federal states, which is distributed in origins according to the product-specific output share by:

$$\ddot{E} = \tilde{E} * \widetilde{\vec{v}}_{k_\iota} \quad (3e)$$

This way, the overall amount of consumption expenditure of federal states does not change. However, the origins of products adapt, modelling interregional trade in accordance to the respective amount of output of federal states.

The same applies for changes in inventories. According to the last few paragraphs of subsection 4.2, we assume that changes in inventories only occur at the place of production. Consequently, we exclude the possibility of interregional trade from changes in inventories, which makes our final matrix look like a block-diagonal matrix with the dimensions of n x b X b x 1, changes in inventories corresponding to only one column of each use table.

$$\ddot{C} = \begin{matrix} c_1 & \dots & 0 \\ \dots & \dots & \dots \\ 0 & \dots & c_b \end{matrix} \quad (3f)$$

Moreover, we assume that the product-specific amount of changes in inventories depends on the amount produced. Accordingly, we distribute the national values of changes in inventories in accordance to the product-specific output share. Matrix C_N contains the national vector of changes in inventories c_N with length n and replicated b-fold at the block-diagonal elements, such as

$$C_N = \begin{matrix} c_N & \dots & 0 \\ \dots & \dots & \dots \\ 0 & \dots & c_N \end{matrix} \quad (3g)$$

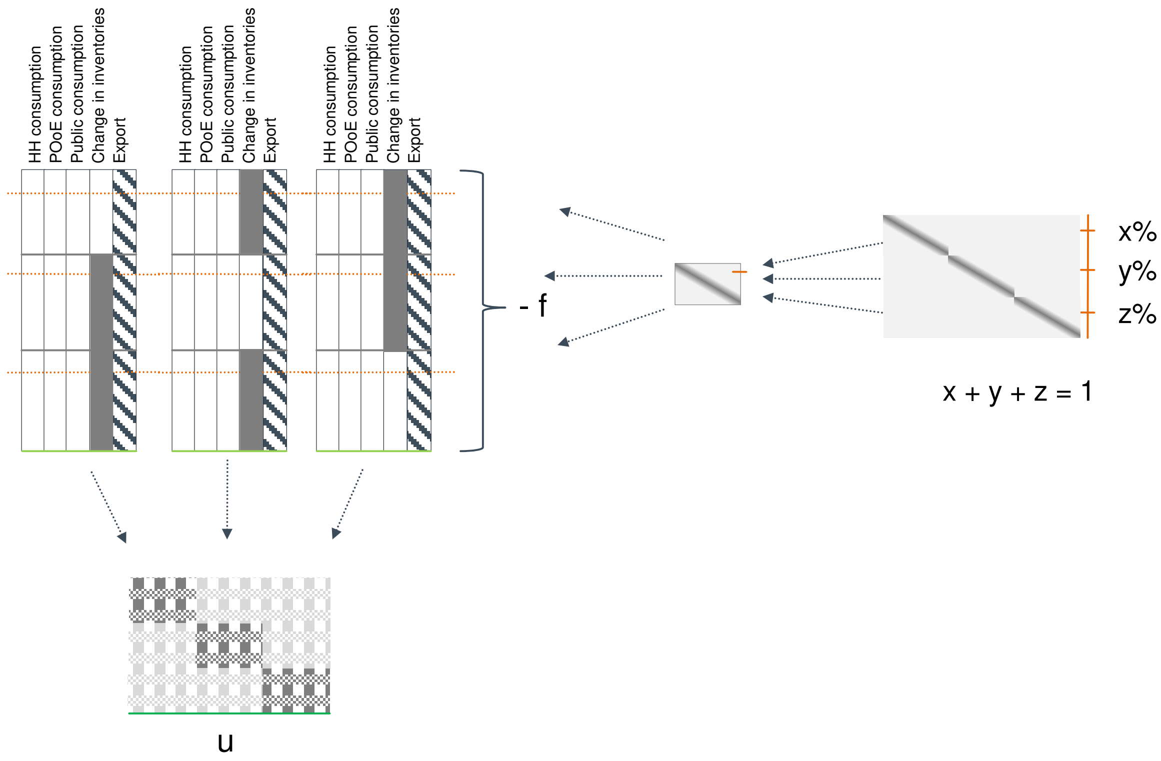
With the product-specific output share already derived in (3d) we obtain our final matrix $\ddot{C}$, representing national values on changes in inventories distributed among federal state in accordance to their product-specific output share:

$$\ddot{C} = C_N * \dddot{\vec{v}}_{k_\iota} \quad (3h)$$

This causes the matrix of changes in inventories to adapt within each iteration as well.

However, since there are single product groups, which show a high amount of changes in inventories and therefore have a high impact on the corresponding output share, there is a special case for which we add a further restriction. This exclusively refers to cases when the absolute value of changes in inventories of a product group makes up more than half of domestic use in the generic national table excluding exports. The latter applies since exports refer to fixed data as well. We exclude these product groups from adjustment according to output share, since the iteratively changing value on changes in inventories has too much impact on output. In these cases we apply the ratio of exports to changes in inventories of generic tables on the fixed values of exports to obtain product-specific values on changes in inventories of federal states.

Figure 11: Calculation of iteratively changing fixed values.



Source: Own illustration.

At the end of this procedure – including special cases - we obtain a new matrix of *changing* fixed values. Within a next step we combine the calculated matrices with information on *constant* fixed values, such as domestic exports or health services. We calculate row sums of the overall matrix in order to obtain $(-f)$.

At this point, we emphasize that we performed this procedure on two different indicators with a different intention each: Adjustments regarding the interregional trade of health product consumption do not have any impact on the overall sum of consumption of each federal state. Hence, no further adjustments are necessary. However, in the case of changes in inventories, we just calculated an adjusted overall sum of this category for each federal state. This is due to our assumption that changes in inventories only occur at the federal state of production. According to the procedure described above, the amount of changes in inventories of a product increases with a higher product-specific output share. This in turn influences the overall amount of changes in inventories of each federal state. Hence, we need to adjust the respective values of the vector $\bar{u}$, which corresponds to intermediate use of industries and final consumption categories, the sum of changes in inventories among them. At the end of this step, we obtain an adjusted vector $(-f)$ and a slightly changed vector $\bar{u}$ with respect to the entries referring to the overall sum of changes in inventories of the federal state. We then proceed with the calculation of rd, applying equation (1).

Over here, we also add a further restriction for cases in which all information on use comes from $(-f)$. This situation implies that the use matrix consists of only zeroes and balancing between supply and use happens between the supply table and $(-f)$. However, equation (1) cannot be applied in this case. Hence, we use a modified version for this case:

$$r_d = \frac{\hat{r}_v P_0^v i}{-f} \tag{13a}$$

and go on with equations (4) to (9).

At the end of this first iteration we calculate the current tables for supply and domestic use by applying equation (10) and (11). This procedure deviates from the original version. Usually, the main decision criterion upon the convergence of the algorithm are the changes of rd and rm to the respective values from the iteration before. In the case these values are below a certain range of tolerance the algorithm is said to have converged. However, in the multiregional case, we have another criterion to be met. We want the sum of each single product over all federal states to meet the national value.

In order to implement this restriction we remove the block diagonal shape of the current multiregional supply table. This way, the number of industries stays equal, representing 64 industries in each of the b regions. However, this matrix only refers to n product categories anymore, opposed to n x b from before. We call this procedure 'to de-diagonalize' the multiregional supply table. $\bar{V}'_k$ refers to the multiregional supply table, while $\widehat{\bar{V}'}_k$ represents its 'de-diagonalized' version.

$$\bar{V}'_k = \begin{matrix} \overline{v'}_{k_1} & \dots & 0 \\ \dots & \dots & \dots \\ 0 & \dots & \overline{v'}_{k_b} \end{matrix} \tag{10a}$$

$$\widehat{\bar{V}'}_k = \overline{v'}_{k_1} \quad \dots \quad \overline{v'}_{k_b} \tag{10b}$$

We know x, the column sums of $\widehat{\bar{V}'}_k$, referring to the industry-specific output of federal states, and the wanted row sums of $\widehat{\bar{V}'}_k$, the national product-specific value. Thus, we apply the GRAS algorithm over $\widehat{\bar{V}'}_k$ until the latter corresponds to national product output. At the end of this procedure we restore the 'block-diagonal' shape again in order to separate federal states from each other again. This yields in $\bar{V}'_{k_{GRAS}}$. This supply table corresponds to national values in both industries and products.

However, we have a special case over here as well, since we know some entries of $\bar{V}'_{k_{GRAS}}$ by definition if all information on use is exclusively included in $-f$, i.e. only consists of exports and changes in inventories and possibly private and public consumption on health. Hence, we include this given information in these cases:

$$\bar{V}'_{k_{GRAS}} = -f \tag{10c}$$

In order to implement information on $\bar{V}'_{k_{GRAS}}$ into our algorithm we compare product-specific information on $\bar{V}'_k$ with product-specific information on $\bar{V}'_{k_{GRAS}}$ and calculate a product-specific rescaling vector.

$$resk_V = \frac{\sum_{j=1}^{j=b*64} \bar{v}_{k_{GRAS_{ij}}}}{\sum_{j=1}^{j=b*64} \bar{v}_{k_{ij}}} \tag{10d}$$

We apply the same procedure to the domestic use table as well. However, we have to define a vector, which incorporates the information on $(-f)$. The denominator refers to the vector of product-specific information from the current domestic use table.

$$resk_{U_d} = \frac{\sum_{j=1}^{j=b*64} \bar{v}_{k_{GRAS_{ij}}} - (-f)}{\sum_{i=1}^{i=b*64} \overline{u_d}_{k_{ji}}} \tag{11a}$$

We apply rescaling vectors $resk_V$ and $resk_{U_d}$ on the matrices Pv and Pd. After that, we restore column sums of Pd and rerun the iterative algorithm.

Again, we have some special cases over here. First of all, $resk_V = 1$ if all information on use is exclusively included in $(-f)$. Second, if $resk_{U_d} < 0$, we rescale the product-specific distribution of concern of Pd to 0.1, since the use table cannot exhibit negative values due to the fact that we determine fixed values on export and changes in inventories.

Third, it appears that values of $resk_{U_d}$ remain far below zero over several iterations. This causes the algorithm failing to convergence if we leave it that way. Taking a closer look at these occasions reveals that this circumstance is attributable to fixed product-specific values being of a higher amount opposed to industry-specific output. This mainly occurs in the Hanseatic cities Bremen and Hamburg when exports are higher than output. This needs us to introduce the possibility of re-exports between federal states, which we have excluded so far. In order to do so, we proceed the following:

The first time, the absolute difference of the multiregional supply table and multiregional domestic use table is smaller than five million, we look at values of $resk_{U_d} < -100{,}000$.[4] We reduce the amount of corresponding exports so it matches product-specific output of the current multiregional supply table and assign subtracted values to re-exports from other federal states. We perform this procedure only once in order to introduce constant fixed values on re-exports. In order to provide the algorithm the correct information on external information, such as the amount of re-exports, from the very beginning, we restart the algorithm with the now adjusted information on exports.

We rerun this iterative algorithm with all its special cases until $\max|r_d - r_{d-1}| < 0.00001$ and max $|r_m - r_{m-1}| < 0.00001$. The moment this applies, we calculate final multiregional supply and use tables according to (10), (11) and (12).

[4] In our setting, this is the case at around 50 iterations.

4.5 First evaluation of the derived multiregional supply and use tables

In this section, we provide a short first evaluation of the derived multiregional tables. A thorough validation regarding the reliability of the developed tables is subject of subsequent papers (Schwärzler & Kronenberg, 2017b, 2017c). Over here, however, we intent to establish an initial assessment of the impact the elaborated algorithm has on the initial tables in order to obtain the final tables.

Golan & Vogel (2000) present their approach to derive the degree of similarity of two matrices in the context of a cross-entropy approach, which is similar to the procedure applied in the RAS family. Their main objective is the same, however, which is to conclude upon the similarity of the initial and the estimated final matrix. Hence, we pursue the same approach, which relies on the log-likelihood, or entropy-ratio statistic *W*. The null hypothesis claims that *W* converges in distribution to ${\chi^2}_{(i-1)*(j-1)}$. Hence, we can test our results under the null hypothesis that A and A_0, which is the final and the initial matrix in our context, are stochastically dependent in accordance to

$$ {\chi^2}_{(i-1)*(j-1)} = \sum_i \sum_j \frac{1}{{a^0}_{ij}} (a_{ij} - {a^0}_{ij})^2 $$

We obtain a χ^2 = 210,000 on 225 degrees of freedom. The resulting p-value << 0.01 indicates that we have to reject the null hypothesis for the domestic use table. Hence, A and A_0 are stochastically independent when we apply this procedure on totaled up federal state matrices as shown in Figure 12 and Figure 13.

This result favors our approach, since we did not put much effort on the compilation of the initial matrix in order to hand this task over to the elaborated algorithm. A high deviation between the initial matrix and the final matrix hence implies that we obtained a great amount of additional information from applying the algorithm.

Figure 12: Aggregated initial domestic use matrix

	BW	BY	BE	BB	HB	HH	HE	MV	NI	NW	RP	SL	SN	ST	SH	TH
BW	578,177	38,844	11,576	8,082	3,230	9,172	23,083	4,823	24,278	47,076	13,685	4,282	12,450	7,744	9,552	7,054
BY	38,068	705,112	13,695	9,559	3,820	10,849	27,315	5,705	28,717	55,697	16,189	5,065	14,726	9,159	11,299	8,343
BE	8,694	10,414	103,636	2,158	862	2,450	6,261	1,287	6,493	12,661	3,678	1,143	3,325	2,070	2,557	1,883
BB	4,679	5,558	1,670	57,174	458	1,304	3,383	684	3,458	6,781	1,969	608	1,770	1,102	1,364	1,002
HB	2,189	2,655	787	550	35,170	624	1,570	328	1,652	3,210	931	291	847	527	650	480
HH	7,565	9,213	2,718	1,899	759	133,664	5,422	1,134	5,738	11,072	3,215	1,006	2,927	1,820	2,246	1,658
HE	18,645	22,494	6,710	4,682	1,871	5,313	287,427	2,794	14,063	27,273	7,931	2,481	7,212	4,486	5,534	4,086
MV	2,963	3,506	1,056	723	289	822	2,147	33,035	2,180	4,285	1,244	383	1,115	695	860	631
NI	19,032	22,688	6,806	4,694	1,874	5,331	13,741	2,799	317,844	27,640	8,029	2,485	7,235	4,505	5,570	4,096
NW	46,880	56,351	16,834	11,703	4,676	13,285	33,711	6,982	35,181	874,505	19,886	6,200	18,032	11,220	13,851	10,214
RP	9,547	11,435	3,418	2,367	945	2,688	6,873	1,412	7,122	13,901	133,108	1,254	3,648	2,270	2,805	2,066
SL	2,563	3,070	919	636	254	723	1,847	380	1,914	3,733	1,085	37,347	981	610	754	555
SN	8,062	9,547	2,876	1,972	787	2,240	5,841	1,175	5,942	11,665	3,390	1,044	107,679	1,894	2,344	1,720
ST	4,301	5,090	1,534	1,051	419	1,194	3,117	626	3,167	6,220	1,807	556	1,620	56,555	1,249	917
SH	6,186	7,438	2,207	1,524	608	1,731	4,455	909	4,594	9,020	2,606	807	2,352	1,463	76,985	1,330
TH	4,114	4,881	1,468	1,008	402	1,145	2,977	601	3,037	5,958	1,731	534	1,554	968	1,198	50,027

Source: Own illustration.

Figure 13: Aggregated final domestic use matrix

	BW	BY	BE	BB	HB	HH	HE	MV	NI	NW	RP	SL	SN	ST	SH	TH
BW	532,759	53,219	10,126	6,121	2,537	9,780	25,676	2,921	25,451	70,600	10,947	3,196	9,717	5,803	7,196	5,130
BY	51,946	636,125	12,659	7,737	3,161	12,181	32,131	3,703	31,933	87,839	13,884	3,955	12,337	7,361	9,074	6,499
BE	8,348	10,735	111,673	1,249	529	2,138	5,453	616	5,029	13,848	2,226	620	1,927	1,150	1,510	1,002
BB	6,035	7,893	1,609	69,417	392	1,576	3,951	476	3,851	10,621	1,715	474	1,504	908	1,147	788
HB	1,962	2,446	443	272	39,486	433	1,176	128	1,202	3,122	483	146	429	254	319	228
HH	4,995	6,296	1,324	748	339	127,051	3,244	358	2,976	8,205	1,325	374	1,164	688	887	592
HE	18,512	23,948	4,909	2,898	1,237	4,874	269,312	1,386	11,445	32,016	5,142	1,425	4,486	2,674	3,405	2,315
MV	4,040	5,285	1,047	660	260	1,032	2,626	45,209	2,592	6,919	1,137	310	1,005	609	773	532
NI	25,045	32,103	6,149	3,789	1,549	5,997	15,767	1,808	313,645	41,971	6,731	1,895	5,871	3,533	4,450	3,121
NW	60,917	79,010	15,915	9,504	3,965	15,642	39,472	4,544	37,776	763,080	16,906	4,798	14,782	8,814	11,235	7,669
RP	12,477	16,307	3,257	1,980	796	3,183	8,116	949	7,848	22,100	150,371	971	3,062	1,849	2,312	1,611
SL	2,879	3,671	709	435	179	688	1,811	203	1,785	5,099	768	44,863	683	405	509	360
SN	12,079	15,543	3,017	1,826	737	2,923	7,621	875	7,439	20,688	3,276	931	125,719	1,704	2,155	1,501
ST	5,778	7,639	1,514	948	371	1,514	3,856	444	3,702	10,503	1,704	456	1,426	69,304	1,107	758
SH	7,954	10,322	2,043	1,265	515	2,051	5,116	608	4,975	13,574	2,193	606	1,926	1,166	91,643	1,010
TH	5,938	7,754	1,516	931	370	1,474	3,845	445	3,733	10,514	1,676	465	1,435	869	1,098	62,949

Source: Own illustration.

Furthermore, we find a high degree of differences between the initial and the final supply table when we focus on one exemplary field of the economy – the pharmaceutical industry – in a next step. These findings support the high impact of our approach, since the final supply table exhibits strongly adjusted production structures of industries. Those altered in the course of the calculation and now reveal certain characteristics in auxiliary production, such as R&D or wholesale among others. Reliability of these emphases in production of federal states have to be tested in a further step, however. This is the goal of a subsequent paper (Schwärzler & Kronenberg, 2017b).

4.6 Calculation of the satellite account from multiregional accounts

At this point of calculation we managed to compute a multiregional account of the overall economy corresponding to the same level of detail of the national special evaluation on supply and use tables. Hence, we obtain one multiregional supply table in the dimension of n x b X 64 x b, n representing the number of products consistent with the national special evaluation, 64 indicating the amount of industries and b referring to the number of regions. Moreover, we calculated multiregional use tables for domestic production and imports in the size of n x b X (64 + 7) x b, including information on both, industries and categories of final use. The use table for imports shows one row in addition, representing information on taxes less subsidies. All tables refer to basic prices.

Summarizing, we established a b X b multiregional framework of national accounts. In the case of compiling the NHA, data on national accounts were provided by the Federal Statistical Office, represented by single supply and use tables. This in turn means, that we have now established the same data base for the multiregional case as was already available for the NHA.

Consequently, the remaining steps of calculating the MRHA refer identically to Schwärzler & Kronenberg (2017a). This is due to the fact that we aim to apply the very same methodology for the multiregional case as was developed for the national case. Since there are no supply and use tables for the German federal states available, it was necessary to establish this primary data base first. Hence, we can proceed to compile the satellite account next.

In order not to replicate the descriptions from Schwärzler & Kronenberg (2017a), we just summarize the calculation steps necessary in the following:

In order to quantify the core area of the health economy, we match data on regional health expenditure with private and government final consumption from multiregional accounts. Next, we apply additional secondary data base in order to quantify the extended area of the health economy. Within further steps we form feasible groups of the health economy in products and industries. As an interim step, we reconcile intermediate consumption patterns in order to honor the health-related characteristics of involved products. After we established the multiregional satellite account comprising supply and use tables, we calculate the multiregional health input-output table (MR-HIOT) from obtained tables. In doing so, we apply commodity technology assumption like in the national case. This approach also refers to the procedure of the Federal Statistical Office concerning the calculation of input-output tables. We adjust the MR-HIOT by manual manipulation in order to handle negative entries evolving from applying the commodity technology assumption.

At the end of this procedure we succeed to compile the MRHA, which consists of one multiregional supply table, two multiregional use tables and one multiregional input-output table. From the derived model we can obtain information on i.e. direct GVA, employment and trade of the health economy in the German federal states. The health economy refers to a product-specific definition and bears information on regional health expenditure in order to obtain a valid quantification. The MR-HIOT does not only allow to conduct input-output analysis in order to evaluate the overall impact of the health economy, but describes interregional dependencies with special emphases on the health economy.

5 Concluding remarks

The MRHA is a further development of the NHA, an already established reporting tool for the national health economy of Germany. It refers to a satellite account of the national accounting framework emphasizing on the product-sided defined health economy. It implements secondary data on health expenditure in order to assure a valid quantification of this cross-industrial sector. For the compilation of the MRHA we aim to use the same methodology, which was developed for the national case in order to assure consistency and comparability of results. Unlike the national case, no supply and use tables are available for the German federal states. Hence, it is indispensable to compile multiregional supply and use tables first. This procedure is in the focus of the present paper.

In order to calculate multiregional supply and use tables for the overall economy, we developed and implemented a new way to multiregionalize national tables. This procedure uses the main principles of the known SUT-RAS Algorithm (Temurshoev & Timmer, 2011) and develops it further for the multiregional case. This MR-SUT-RAS is an iterative algorithm, which is applied on an initial multiregional table in order to update it to given regional data. This provided regional data refers to output and intermediate use of industries and use of final consumption categories. Moreover, the approach takes into account given information on fixed values, i.e. on exports or any other values we can specify precisely. A special feature of the SUT-RAS and consequently the MR-SUT-RAS is that it includes given information and simultaneously applies it in the supply and use tables. Hence, no further adjustment is necessary after performing the algorithm since all information available is considered within the procedure. Moreover, the algorithm considers the process of balancing supply and use tables. The resulting multiregional tables correspond to the national tables in the sum of industries and products.

We are well aware of the fact that this procedure, like most other approaches concerning the (multi-)regionalization of national accounts, cannot keep up with survey-based tables. Hence, we aim at a holistic approach of our model. This means, we do not pursue accuracy in each cell of the tables, but an accurate picture of economic flows. We specifically make use of a closed mathematical model in order to rely on a rather mechanical approach. It makes use of the interdependencies of the economic cycles of supply and use.

The developed approach involves a more pronounced mathematical background than the FLQ or CHARM approach, and challenges some of their essential drawbacks. However, its first implementation takes more effort as well. The circumstance that misspecifications often lead to a non-converging algorithm, is both a blessing and a curse of this approach. However, everyone, who is capable of algorithm programming and with sufficient knowledge of national accounts can apply this algorithm. There are no specific requirements concerning hardware and software to be met. For the implementation we used the free statistical software R at a standard computer with extended working storage capacity of 16 GB RAM. Moreover, the procedure can easily be applied to multiregionalize national accounts from other countries as long as sufficient data is available.

Certainly, there is a potential for improvements of the current MR-SUT-RAS algorithm. Most of it refer to additional data. However, data has to fit the framework of national and regional accounts, otherwise additional assumptions have to be taken, which might have a reverse effect on overall data quality in the end. In the case of regional accounts, in turn, more data is actually available opposed to what we were able to access, suggesting implementing a revised data base in future.

Another critical factor is the compilation of the initial matrix and the resulting amount of cross-hauling. However, we do not want to put too much emphases on this matter in order to keep the focus on the algorithm and its power first. Moreover, we applied the same idea of regional openness among all federal states in the same way, never putting any emphases on special regions. This was necessary in order to observe the power of the algorithm in depicting specific characteristics of federal states. This way, each federal state was treated identically. Hence, we think that this leads to a general bias of a direction unknown, which, however, makes it possible to compare results among regions.

The developed model at hand exhibits some specifics, which favor a thorough validation of results within a next step. First, the model builds up on a special evaluation of national supply and use tables and hence offers a high degree of detail on the product side. Moreover, we calculated a satellite account in a final step. This one allows to evaluate the product-sided defined health economy. This enhances a variety of analyses, i.e. on the regional production structure of health products, such as regional specialization in production processes, in retail or in research and development. Putting emphasis on the field of the health economy makes it easier to develop a proper assessment on the quality of results. The field of health economy has for long now been our field of expertise, not only from a theoretical, but also from a practical approach. Hence, we see a great advantage in the further development into a satellite account.

Further contributions will focus on the results of the MRHA in order to evaluate the quality of the developed approach. We will look at both, direct effects (Schwärzler & Kronenberg, 2017b) and spill-over effects (Schwärzler & Kronenberg, 2017c) and will even question time series results of direct effects (Schwärzler & Kronenberg, 2017b). Moreover, we will apply the model to a certain economic policy issue – lagging investments in German hospitals (Schwärzler & Kronenberg, 2017d).

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