Harmonization of regional and national input-output models: the case of Germany

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Introduction

Despite its federal structure Germany does not have official input-output tables at the subnational level. Although some regional statistical offices produced input-output tables in the past, these efforts have been discontinued in the 1990s. However, in the last few years there has been a resurgence of input-output modelling at the regional level, and input-output tables have been constructed, for instances, for the regions of Mecklenburg-Vorpommern (Kronenberg, 2010), Hamburg (Kronenberg & Engel, 2008), North Rhine-Westphalia (Kronenberg & Többen, 2011) and Thüringen (Dettmer & Sauer, 2014). Thanks to these efforts, there is now a much better foundation for regional economic studies than in the past.

At the same time, at the federal level there are input-output models which have been extended and thereby increased significantly in terms of complexity, for example INFORGE (Maier et al., 2015). This is a macro-econometric input-output model fully consistent with the national economic accounts including the national input-output table, containing 63 branches, a detailed foreign trade module with 156 trading partners and 40 commodity groups, consumption expenditure by private households based on the household consumption survey, consumption by the government divided into different purposes, investment by investing branch and divided into construction, equipment and other investment. The model also includes a disaggregated labour market with 63 branches, 50 occupation areas and 4 qualification levels. The regionalisation of the model results rely on a regional module which partly considers input-output relations.

Considering the availability of complex models at the national level and the increasing availability of regional input-output accounts raises the question how this wealth of data and model extensions can be usefully combined. In particular, we address two concrete questions:

1. For which regions do recent input-output tables exist?
2. How can these different tables (constructed by different authors using different methods and classifications) be made consistent with each other and with national models?

Concerning the first question we present a survey of the regional input-output tables that have been published since the turn of the millennium. We do not claim completeness, since some of the studies in this field are relatively hard to find. It is possible that some existing tables are missing in our survey. We would appreciate it if readers could make us aware of further existing RIOT:

To tackle the second question we sketch a possible modelling approach which allows a consistent modelling of national and region-specific economic development paths. The goal of this approach is a harmonization of the two levels, which means that information flows in both directions. The goal is not a simple “breaking down” of national developments at the regional level(s). The application of the approach raises certain challenges that must be overcome. We develop some preliminary solutions and highlight avenues for future research.

Regional input-output tables since 2000

Tables for federal states

Since the year 2000, a number of input-output tables have been produced for individual states. However, they are generally hard to find and many of them have not been published at all. Table 1 provides an overview over the tables of which we are aware and the corresponding publications.

Table 1: Input-output tables for German federal states

State	Producer(s)
Baden-Württemberg	Haigner et al. (2015)
Baden-Württemberg	Heindl & Voigt (2012)
Hamburg	Prognos (2009)
Hamburg	Kronenberg (2011)
Hessen	Penzkofer (2002)
Hessen	Koschel et al. (2006)
Lower Saxony	Schröder (2012)
Mecklenburg-Western Pomerania	Kronenberg (2010)
Nordrhein-Westfalen	Kronenberg & Többen (2011)
Nordrhein-Westfalen	Prognos (2007)
Sachsen	Lehr et al. (2013)
Thüringen	Dettmer & Sauer (2014)

Source: compiled by the authors

Baden-Württemberg is the state with the strongest tradition in regional input-output modeling. Its statistical office actually produced input-output tables for several years in the 20th century (SOURCE). The publication of official IOT's ceased in the mid-nineties. However, a number of researchers and research institutes have produced unofficial IOT's for Baden-Württemberg in recent years.

Haigner et al. (2015) describe the construction of a RIOT for Baden-Württemberg. Their goal was to identify the effects of a special programme by L-Bank intended to promote the founding of new enterprises. To this end, they constructed a RIOT for Baden-Württemberg with 51 branches. The methodology is based on CHARM, although it is not described in detail. The table itself is not published. Apparently the authors use a pure nonsurvey approach.

Heindl & Vogt (2012) develop a RIOT for Baden-Württemberg to study the employment effects of regional climate policy. In terms of data they use the NIOT for 2006, consumption data from the LWR, and employment data from the BA. Then they employ CHARM to regionalize the NIOT and develop a RIOT for Baden-Württemberg. The entire RIOT is printed in the appendix of Heindl & Vogt (2012), and the authors offer it as an Excel file available upon request.

We are aware of two regional input-output studies for **Hamburg**. The first was produced by Prognos (2009). In the middle of the worldwide economic crisis following the financial crash of 2008, the regional government of Hamburg implemented an economic stimulus program to support the regional economy. Prognos construct a RIOT for Hamburg to assess the effects of that program. As a basis for the RIOT they used an aggregated version (12x12) of the NIOT. The regionalization was based neither on LQ nor CB. Instead they derived import shares for each industry from other studies and an econometric approach based on earlier unpublished work by Prognos. They do not publish the RIOT itself, but they do report the I-O coefficient matrix.

Another RIOT for Hamburg was constructed for the INFRADEM project, whose goal was to study the effects of demographic change on energy consumption in selected regions. Kronenberg & Engel (2008) and Kronenberg (2011) report the results. The RIOT for Hamburg was constructed with the help of CHARM and EVS data. The RIOT itself was not published.

For the state of **Hesse**, a RIOT was constructed to estimate the effects of trade fairs in the city of Frankfurt. A publication in ifo Schnelldienst reports the main findings of the study, but it does not explain how the RIOT was constructed (Penzkofer, 2002). A longer version of the report probably exists, but it does not seem to be available online.

Another RIOT for Hesse was constructed in the context of the InKlim 2012 project (Koschel et al., 2006). The authors of this study used the simple LQ method to regionalize the NIOT from 2000. The resulting RIOT for Hesse has 18 branches.

An input-output table for **Lower Saxony** was produced by Schröder (2012). It was used to study the effects of wind energy on the regional economy. The author first produces a regional supply table and then proceeds with the construction of a regional input-output table. He uses the NIOT of 2007 and EVS data for 2003. The resulting RIOT for Lower Saxony has 71 branches. The publication (Schröder, 2012) includes an aggregated version (16x16) of the RIOT.

In the context of the aforementioned INFRADEM project, a RIOT was also constructed for **Mecklenburg-Western Pomerania**. The procedure is described step by step in a paper published in *AStA Wirtschafts- und Sozialstatistisches Archiv* (Kronenberg, 2010). The RIOT for this state refers to the year 2003 and is based on the NIOT of the same year and the EVS household survey from 2003. CHARM was used to regionalize the NIOT, and further regional data were used to improve the quality of the RIOT. The full version of the RIOT has 71 branches; an aggregated version (16x16) was published.

We are aware of two RIOT for **North Rhine-Westphalia**, the largest state in terms of population and GDP. One of them was developed by Prognos to study the effects of hard coal mining on the regional economy (Prognos, 2007). The methodology appears to be similar to the one used for Hamburg (Prognos, 2009). This RIOT for North Rhine-Westphalia has 12 branches, it has not been published.

Another RIOT for North Rhine-Westphalia was constructed by Johannes Többen in the context of his diploma thesis. The methodology relies on CHARM and EVS data, it is explained in Kronenberg & Többen (2011). This RIOT for NRW has 71 branches; an aggregated version (16x16) has been published.

Lehr et al. (2013) report that a RIOT was constructed for **Saxony**. Their research goal was to identify the effects of Saxony’s agricultural sector. As a basis for the RIOT they used the NIOT for 2006 and EVS data from 2008. The methodology relies on CHARM and EVS data as suggested by Kronenberg (2010). Their study is particularly interesting because in addition to the nonsurvey estimation they also use a detailed survey of the regional agricultural sector. The RIOT includes a 12x12 interindustry transactions matrix. It is not included in the project report (Lehr et al., 2013).

A RIOT for **Thuringia** has been produced by Dettmer & Sauer (2014). It was used to study the effects of an investment project (more precisely, a pumped storage hydropower plant) on the regional economy. Sauer & Dettmer (2014) produced an IOT for Thuringia for the year 2010, using the NIOT of the same year and EVS data from 2008. Instead of CHARM they employed the FLQ method to regionalize the NIOT. In contrast to some other studies, they explain their approach in a very detailed and transparent manner. The RIOT includes 51 branches; it was not published.

More recently, a number of studies on the regional effects of the health economy have been performed by the research institute Wifor (Legler et al., 2016, Ostwald et al., 2014, Ostwald et al., 2015a, 2015b, 2015c, 2017). They have constructed specialized RIOT with a focus on the health economy for Hamburg and Thuringia (using FLQ), Baden-Württemberg, Mecklenburg-Western Pomerania, Berlin/Brandenburg, and Hesse (using a combination of SUT-RAS and CHARM).

Furthermore, DIW Econ has performed a number of studies that seem to be based on regional input-output analysis (Mattes, 2014, Mattes et al., 2014, Pavel et al., 2015). However, the description of the underlying methodology is very short and does not describe if and how actual input-output tables were produced.

We were unable to find input-output tables for the following states: Bavaria, Berlin, Brandenburg, Bremen, Rhineland-Palatinate, Saxony-Anhalt, Saarland, Schleswig-Holstein.

Tables for other regions

In some cases, researchers have focused on regions that are smaller than federal states. We are aware of the following studies.

Table 2: Input-output tables for other regions

Region	Producer(s)
Hanover	Schröder (2010)
München	Prognos (2010)
Baltic Sea Coast region	André Schröder, Karl Zimmermann
Region Frankfurt	ifo Institut

Source: compiled by the authors

The economic effects of renewable energy on the region of **Hanover** were studied by André Schröder (2010). Using CHARM he regionalized an aggregated version (12x12) of the NIOT for 2006. The procedure is well-documented.

Prognos (2010) reports that a RIOT for the metropolitan region of **Munich** has been constructed. The RIOT itself is not published, but the appendix of Prognos (2010) includes a 12x12 matrix of the input-output coefficients.

Schröder & Zimmermann (2014) discuss the possibilities of constructing a RIOT for the **Baltic Sea Coast region**. Rather than producing a complete RIOT, they decide to regionalize the matrix of output multipliers computed from the NIOT.

The aforementioned study by ifo about the effects of trade fairs also includes an input-output analysis for the **Frankfurt** region. Details on the RIOT or its construction are not reported.

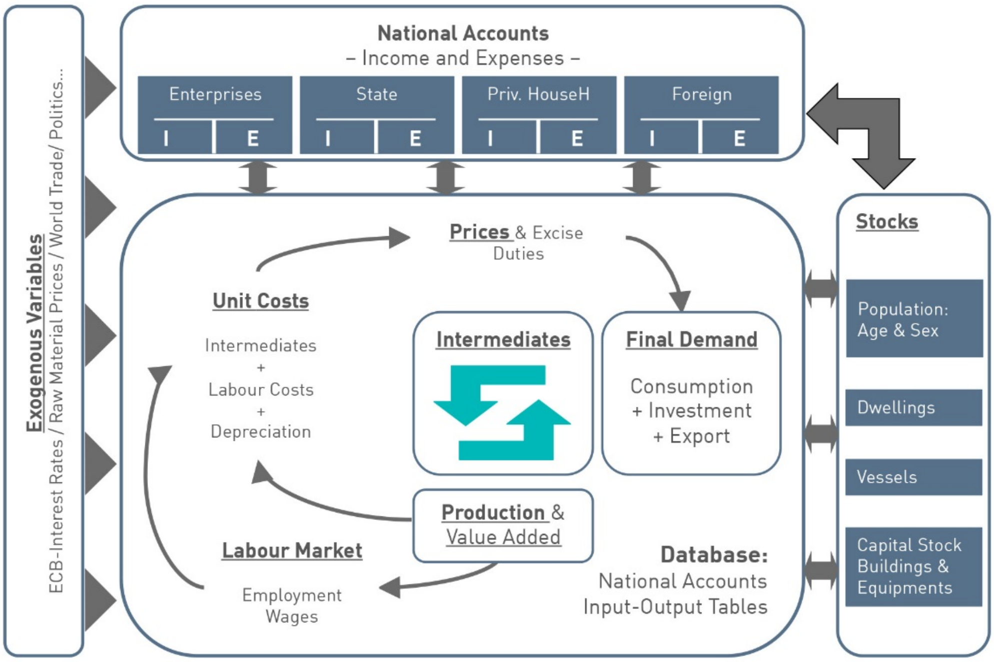
The INFORGE model

INFORGE (inter-industry forecasting Germany) is a forecasting and simulation model which can be used to analyse the effects of structural changes in the German economy. INFORGE was developed by GWS in 1996 and has been regularly updated and developed since (e.g. Maier et al. 2015, Wolter et al. 2016). INFORGE is a macroeconomic input-output model (Eurostat, 2008, p. 527) which is distinguished by its empirical specification and is constructed around the interrelationships between individual industrial sectors. Because the quality of the data used is vital, it uses only official data sources from the German Federal Statistical Office, in particular national accounts and input-output tables, and other data from domestic and international public organisations. INFORGE belongs to the group of INFORUM-models (Interindustry Forecasting at the University of Maryland). The INFORUM approach were started by Clopper Almon (Almon 1991).

INFORGE's strength is its ability to analyse complex socioeconomic and economic structures including their dependencies. The input-output relationship also allows the identification of direct and indirect effects and cause-effect relationships. This enables end-to-end modelling of interdependencies between individual industrial sectors, as well as an explanation of macroeconomic relationships which treats an economy as the sum of its individual parts.

An important feature of the INFORGE model is the inclusion of detailed trade data through the integration of the global trade model TINFORGE (Großmann et al. 2015). The specifications for export demand thus take into account not just the economic power of Germany's trading partners and their proportion of trade, but also distinguish between tradable goods categories. The model incorporates data for a total of 150 countries and 40 goods categories. This detailed treatment of German export demand enables in-depth analysis of the German economy against the backdrop of globalisation.

Figure 1: Structure of the INFORGE model



Regionalisation of INFORGE results

By applying the LÄNDER-model (Wolter, Ulrich 2013), the INFORGE results are used for simulations and projection on the regional level. The model LÄNDER projects labour demand for 25 industries for each of the 16 federal states of Germany. It uses elements of the shift-share-analysis.

At the beginning in the 1990s, LÄNDER estimated labour demand ***ld*** for a federal state ***f*** and an industry ***i*** at time ***t*** as a function of the labour demand in Germany **LD** in the same industry and a time trend ***T***:

$$\ln(ld_{f,i}[t]) = a + b\ln(LD_i[t]) + c\,T$$

The estimated functions (16 federal states and their 25 sectors) gave information about the joint development (elasticity b) and the specific regional impacts (coefficient c). This model was able to make a consistent projection of labour demand for each federal state, but was not able to give an explanation for different developments because of specific regional variations. The model missed important impacts e.g. different population (***pop***) developments. Therefore, regional distribution of population was introduced to the model.

$$\ln(ld_{f,i}[t]) = a + b\ln(LD_i[t]) + c\,T + d\ln\left({pop_f[t]}/{pop[t]} \right)$$

But the indicator population cannot be used for all industries: medical and health care or construction (housing) are influenced by population and its regional distribution, however, the impact is rather small for manufacturing industries. Instead, the manufacturing industry exports more than 50 % of its products and consequently the development of world trade is more important for manufacturing than population. This consideration leads to different approaches for industries using different leading indicators.

From INFORGE, we know, that the production of some industries (e.g. business services) strongly depend on intermediate demand. Production by sector and a matrix of input coefficients are needed for calculating intermediate demand. The Federal Statistical Office of Germany and the offices of the federal states provide no accessible information for production on the regional level. For some industries we have turnover, labour costs and purchases. For all federal states and industries value added and labour costs are available. We also know the relation of intermediate inputs and value added on the national level. These information are combined. As a result we gain an approximation of production ***prod*** for each federal state ***f*** on the sectoral level ***j***. The next approximation is the use of the coefficient matrix ***A*** of Germany. By putting it all together, we can calculate an indicator for the intermediate demand (IDind) on the regional level **f** for a specific industry **i**:

$$IDind_{f,i}[t] = \sum A_{ij}[t] * prod_{f,j}[t] \;\; \forall\, j \neq i$$

In consequence, it is possible to estimate shift-share functions for some industries with indicators of intermediate demand.

$$\ln(ld_{f,i}[t]) = a + b\ln(LD_i[t]) + c\,T + d\ln\big(IDind_{f,i}[t]\big)$$

The upper function links labour demand of federal states to the national and regional level. But this estimation approach can only be used for few industries. This approach shows the lack of data on the regional level: Labour demand function, for example labour demand depends on production, relative prices and technological trends, cannot estimated directly. Only if regional IO-Tables are available, it is possible to estimate production or unit costs correctly to drive labour demand, wages and prices. Furthermore the main reasons for future changes in production can be analyzed using a RIOTs.

Discussion

For projections of regional labour markets, some information on interindustry transactions is thus extremely helpful. Ideally we would like to have 16 RIOT, one for each of the 16 states. As we have shown above, some RIOT have been constructed in recent years. However, most of them have been published and are not available for other researchers. Moreover, even if we managed to collect all the existing RIOT there would still be problems because they lack consistency. First, there is the classification issue. Some of them still follow the CPA 2002 classification, whereas the newer ones are based on CPA 2008. Second, the existing RIOT differ in the way in which imports are allocated. In some cases imports are allocated directly (Type B tables) but in many cases they are allocated indirectly (Type E tables). As a result, the input-output coefficients from the different tables are not comparable and cannot be used in a single consistent modelling approach. Finally, some of the existing RIOT are highly disaggregated (up to 71 branches) but some of them offer much less sectoral detail. If all the existing RIOT were used in one single model, the approach would have to work with the highest aggregation level (12x12), which implies that a lot of valuable product- and industry-specific information would be lost.

A scientifically satisfactory solution to the problem would be the construction of 16 RIOT, one for each state, according to a single approach and using the same level of aggregation. These tables could then be linked to INFORGE to produce better projections of regional labour market developments and explain better its driving forces. The problem with this approach is that it would require a massive investment in terms of time and other resources.

We therefore propose a step-by-step approach. Instead of working with a number of mutually inconsistent RIOT from different sources, we plan to develop RIOT for two of Germany's 16 states in the near future. These RIOT will be based on one methodological approach, using the same classification and aggregation. They will both refer to the year 2013. The next step will be to link each of these tables with INFORGE and experiment with the linked model(s). This will allow us to test, for example, to what extent the results of the overall model depend on the state for which a detailed table is available. The results for the regional labour market of the regional model will be compared to the existing projections of the LÄNDER-model. It is also to combine the regional IO-model for one country with the LÄNDER – model. If the results turn out to be encouraging, we will develop a model with both RIOT linked at the same time. In principle, this approach can be followed to its natural conclusion when a RIOT for each of the 16 states is linked to INFORGE.

A radically different approach would be to start with a MRIO model that includes all 16 states (but not separate model for Germany as a whole). Fortunately, a MRIO for Germany has been constructed by Többen (2017). While theoretically interesting, such an approach would generate massive obstacles before it could work. INFORGE includes a large number of econometrically estimated behavioural equations. Building a MRIO INFORGE from scratch would require all these equations to be re-estimated in a MRIO setting. The handling of such a large model would also be difficult from a computational point of view. Moreover, it is not clear *a priori* if a MRIO approach would really be superior to the step-by-step approach sketches above. In a federal state like Germany, many developments take place at different administrative layers. This includes the administration of public funds as well as the social security system. It therefore makes sense to have different levels of regional aggregation and administration (the state level as well as the federal level) in a model. A MRIO would only consist of 16 regions but no super-regional administrative layer.

Another alternative would be an approach that combines features of the 16-steps approach and the MRIO approach. As soon as a RIOT for one state ("A") exists, it is relatively easy to construct a BRIO table, which would include state A as one region and the rest of Germany as the other region.

Conclusion

To conclude, we return to the two questions mentioned in the introduction. The first question referred to the availability of RIOT for the 16 German states. Our literature survey reveals that RIOT have been constructed for eight of the 16 states in recent years. It is possible that there are some more RIOT of which we are unaware. Hence, the availability of RIOT has improved considerably. Roughly ten years ago it was common for researchers to complain about the lack of RIOT in Germany. Such complaints are no longer appropriate. There are relatively recent RIOT for at least half of the 16 states.

However, many of the existing RIOT have not been published and some of them are not even well-documented. For the sake of scientific progress it would be better if developments in RIOT construction were more widely published. However, there seem to be very few good outlets for this kind of scientific work. As most readers probably know, scientists today are forced to publish regularly in "high level" journals. Our own experience as well as the literature survey above indicate that it is hard to publish papers on the construction of RIOT in these journals. We have the impression that the fields of economics does not sufficiently appreciate the work that goes into the construction of these tables (and other datasets). To improve the dissemination and appreciation of RIOT construction (or, more generally speaking, dataset construction) we suggest that journals should be more open to this kind of work. The chance to publish papers in peer-reviewed journals would provide a much greater incentive for RIOT producers to make their work available to others.

Concerning the second question about the harmonization of the existing RIOT and the INFORGE model (or other models based on the NIOT), we come to a rather pessimistic conclusion. The existing RIOT are simply too different to serve as a common basis for a single model. Rather than tampering with the existing RIOT and trying to “force” them into a common model framework, it is probably more worthwhile to develop a new set of RIOT that are consistent with each other and the NIOT.

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