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The TIGER Model: Application of detailed passenger and freight transport in a regional CGE setting

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The TIGER Model: Application of detailed passenger and freight transport in a regional CGE setting

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The present paper describes the construction and first empirical application of the TIGER model (TIGER is an abbreviation of “Transport and Infrastructure General Equilibrium model for Regions”). The TIGER model belongs to the group of regional CGE models, applying a mix of conventional modelling techniques used in standard computable general equilibrium models and New Economic Geography elements. The TIGER model can be used to evaluate transport policies on economic and environmental effects. Innovative features of the TIGER model are the detailed modelling of the transport sector and modelling of commuting and migration decisions. The approach of the TIGER model is to model cross-border related transport policies on a disaggregate level, with freight and passenger transport flows, allowing for different transport modes (road, water, rail), distinguishing between public and private transport, and for different transport motives. Commuting trips will be modelled in detail, by a location-attraction function, jointly determining area of residence and place of work.

The TIGER model is constructed as a regional model on the NUTS-3 level for Belgium, the Netherlands, Luxemburg and a part of Germany, where regions are linked by interregional trade flows, transport trips and migration. In a similar way the model can be extended to all NUTS-3 regions in Europe. This paper will relate on the construction of the database for the model and the addition of innovative elements in the model, necessary to model transnational passenger and freight flows. The construction of the model is based on the available data in the TRANSTOOLS database.

The detail offered by the TIGER model allows for a quantitative evaluation of effects of several transport policies with a transnational dimension in the Benelux and Germany. We will present results of the TIGER model based on a current project in the Benelux.

Keywords: Regional general equilibrium model, new economic geography, passenger transport, commuting, migration

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1. Introduction

1.1 The case for an economic model of the Benelux

The Benelux Union, composed of Belgium, Netherlands and Luxemburg has been a laboratory for economic and political cooperation within Europe, since its humble beginning as a customs union in 1944. Serving as one of the corner stones of the European Union, this region is well known for its high degree of economic integration, crossing language, cultural and country borders. The Benelux is one of the gateways to Europe, holding 3 major ports (Antwerp, Rotterdam and Amsterdam) as well as several smaller ones (Terneuzen, Zeebrugge, Oostende, Den Helder). These ports ship a large share of intermediary and final goods that will eventually find their destination in the Benelux and the rest of Europe. Witnesses of the importance of these ports are the cross-boarder railway and highway connections, which serve specialized industries in the hinterland.

Benelux is thus as a key region for freight transit, but passenger flows also becomes steadily more important. Labour mobility in Europe has increased, following the trend of more knowledge intensive and innovative economic activities, dependent on a skilled and mobile labour force. At the same time, cross-boarder commuting and migration of low, middle and high skilled labour become more common.

This means that besides being a “European laboratory” the case of the Benelux also presents an excellent “economic modelling laboratory”. Benelux trade and transport interactions are interesting from an analytical point of view and numerous policy and management questions arise when cross-boarder interactions or large investments in inter-country infrastructure are envisaged. Some examples of these policy cases are: the Iron Rhine railway connection, the Gent-Terneuzen Canal, spill-over effects of improvements in infrastructure on other regions and countries, port competition between Antwerp, Rotterdam and Amsterdam in terms of accessibility to the hinterland. A more policy related issues is the implementation of a road charging systems under discussion for the Benelux region, both for passenger and freight transport.

Taking into account that the Benelux has quite some regional disparity, with concentration of economic activity around large ports and in regions with administrative and historical importance or a good accessibility to commuting and freight traffic, there is a case for developing a model integrating transport modelling, cross-boarder interactions and region specific detail. The framework for such a model is available as well as the state-of-the-art techniques of regional socio-economic modelling developed over the last decade.

1.2 Spatial general equilibrium models

The current paper will discuss the construction of a detailed regional economic model, making use of the framework of spatial general equilibrium theory. Computable general equilibrium models (or CGE models) offer a framework to model the full level of

economic interactions, based on input-output tables and national account data. SCGE models typically are comparative static equilibrium models of interregional trade and location based in microeconomics, using utility and production functions with substitution between inputs, usually modeled using constant elasticity of substitution (CES) equations. Since the ‘revival’ of regional economics, partially attributed to the work of Krugman, Venables and Fujita (1991), many SCGE model incorporate the monopolistic competition framework of Dixit-Stiglitz (1977) to model the effects of regional competition and concentration of economic activity.

During the past decade, several SCGE models have been developed for the analysis of policy related questions, especially when involving the regional interactions and/or transport or the analysis of regional disparity. Some examples of well known CGE models with disaggregation on the level of regions are CGEurope (Bröker et al, 2001) , the IFPRI model (Thurlow J, 2008), RELU, RAEM (Thissen et al., 2004) REMI, WorldScan, GEM-E-3 (Capros et al, 1997), etc. The present SCGE models have a sophisticated theoretical foundation and rather complex, non-linear mathematics. The latter is precisely the reason why SCGE models are able to model (dis)economies of scale, external economies of spatial clusters of activity, continuous substitution between capital, labour, energy and material inputs in the case of firms, and between different consumption goods in the case of households.

Our attention will go to those SCGE models with a detailed specification of transport network, land-use and economic interactions such as RELU and CGEurope. The main basis and logical assumptions of SCGE can be summarized in a few lines:

- 1) Interaction between regions is costly and requires transport, which is essential in the model.
- 2) The further two regions are apart, the more costly the interaction (increased transport and trade costs)
- 3) Trade interactions are modeled with CES functions, applying the Armington-assumption. The Armington assumption states that imported and domestically produced products are imperfect substitutes (or varieties) and that consumers prefer a ‘balanced’ amount of these goods.
- 4) Passenger and freight transport behave differently. Freight transport is often modeled in much more detail and is the main source of interaction between regions
- 5) Supply should equal demand on regional level, reflecting market clearance.
- 6) In the framework of Dixit-Stiglitz monopolistic competition, increased concentration of industries increases the variety to consumers and leads to bonuses in terms of proximity.

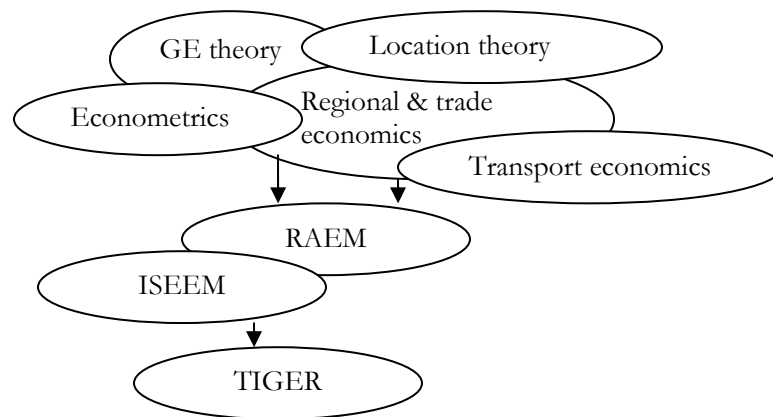
The application of SCGE models are mainly focused on regional infrastructure investments, policy related issues such as road taxes or road charging and regional planning (housing, labour market policy, land use).

2. TIGER: a spatial general equilibrium model for the Benelux

2.1 The RAEM family of models

TIGER fits within the main model development work of general equilibrium models undertaken by TML and TNO, starting from the first version of the RAEM model Thissen et al (2004) and Ivanova et al (2007) for the Netherlands. By now, one can refer to a basic framework for SCGE models called ‘the RAEM family’ of models, covering a large variety of modelling techniques, expertise and know-how. The RAEM modelling framework integrates both conventional and non-conventional ideas in general equilibrium modelling and regional economics and is being under constant revision and updating (Figure 1).

Figure 1: The RAEM family of models



TIGER is the latest spin-off from this ‘RAEM family’ and is the first to model inter-country interactions with a detailed transport market. The TIGER model incorporates Belgium and the Netherlands with a NUTS-3 regional disaggregation and contains an extension to Germany, which is disaggregated on the NUTS-1 regional level.

TIGER was constructed, working upwards from the related ISEEM (Ivanova O, Heyndrickx C. et al, 2009) and RAEM models, which were developed respectively for Belgium and the Netherlands. The database for the model was based on the databases of the country level models, but was cross-checked with new national account data and recalibrated; a new database was produced for Germany. The basic modelling framework of TIGER is similar to RAEM. The main differences between the two models are related to the disaggregation of the transport sector, the labour market specification and the introduction of multiple countries, involving cross-boarder trade.

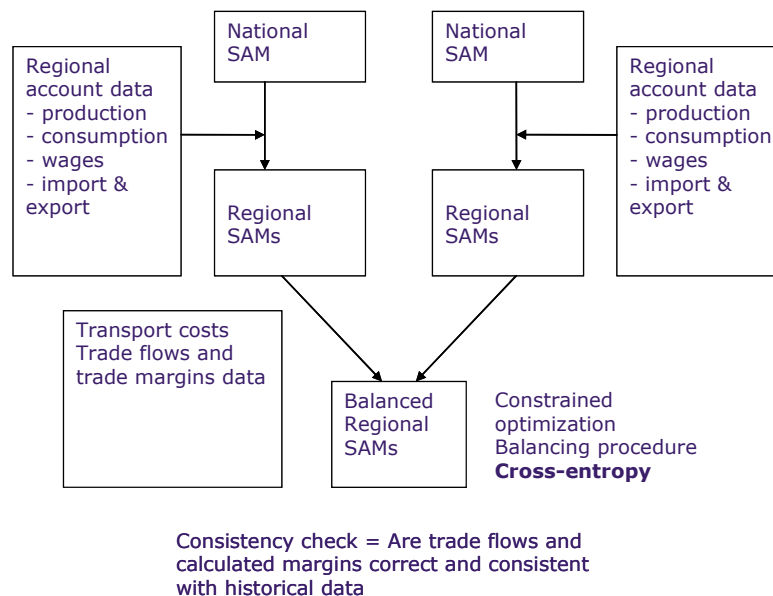
TIGER aims to be a flexible tool for analysis and research, focusing on cost-benefit analysis and transport related policies and investment projects. TIGER models freight and passenger flows separately, where passenger flows are related to commuting (both within the country as cross-boarder) and interacts directly with the consumer welfare. TIGER distinguishes different transport modes, public and private transport and service and goods trade with a detailed sector specification.

2.2 Construction of the model

General equilibrium models require a calibrated database, based on input-output and supply tables, national (regional) account data. Input-output tables are produced periodically by national statistics offices, but are normally lagging behind on the real economy. For the TIGER model, input-output tables of 2004 are used of Belgium, Germany and the Netherlands. More recent national account data was used to update the baseline of the model to 2007.

The calibration of the database is largely implemented in the model code, where the national social accounting matrices for Belgium, the Netherlands and Germany are step by step disaggregated and rebalanced to generate regional social accounting matrices. In the first disaggregation phase, the national social accounting matrix is split-up using a top-down process, with the help of auxiliary regional account data. During this first phase, the internal consistency of the regional matrices needs to be satisfied. With this, we mean that all factors of production (labour, capital and land), as well as the intermediate goods should be accounted for and balanced to the regional production.

Figure 2 Construction of the database



In the second phase we have to balance the external consistency of the regional matrices, meaning that supply and demand should be equalized both on country and on regional level. In this phase we have to make sure that all production is either exported to other regions or to the international market or consumed within the region. This explicitly implies that export should not be larger than production. Vice versa, we have to make sure that all consumption is guaranteed in terms of imports, interregional or international, or regional production. Implementation of transport and trade margins in the data requires that the cost of the imported good rises with the distance from the producing region. The balancing procedure used during this phase is the cross-entropy method.

2.3 Theoretical framework of the model

The model utilizes the notion of aggregate economic agents. They represent the behavior of the whole population group or of the whole industrial sector as the behavior of one single aggregate agent. It is further assumed that the behavior of each such aggregate agent is driven by certain optimization criteria such as maximization of utility or minimization of costs. The model is neo-classical and assumes average costs pricing and no excess profits. The excess profits are normally due to the existence of monopoly or oligopoly on the market. Normal profits of the firms are paid in the form of dividends (return to capital) to the households who own all capital goods in the economy.

The micro-economic behavior of the following economic agents is included:

- At the regional level – one aggregate household type by region, production sectors differentiated by NACE95 classification categories; wholesalers differentiated by NACE95 classification categories;
- At the national level - investment banks; federal governments and external trade sector.

Households

Each household spends its consumption budget on services and goods in order to maximize its satisfaction from the chosen consumption bundle. Households have substitution possibilities between different consumption commodities. In the model these substitution possibilities are captured by Stone-Geary utility function, which corresponds to the Linear Expenditure System (LES) of demands. According to the Stone-Geary utility function a household derives its utility only from the amount of consumption, which is higher than the minimum subsistence amount and the elasticity of substitution between commodities is equal to one. In case of all subsistence amounts being equal to zero, the Stone-Geary utility function reduces to the Cobb-Douglas utility function.

Labour market and unemployment

Unemployment is based on a regional search and matching model, which represents a wage curve for the representative household(s). Increased access to a labour market reduces the search cost for specific labour types, which leads to efficiency gains for the economy. The level of the unemployment benefits, received by the household, depends upon the level of unemployment of the individuals within the household.

Firms

At each time period, the instantaneous behavior of the sectors is based on the minimization of the production costs for a given output level under the sector's technological constraint. The level of the sectors' output is equal to the aggregate demand for its production, which reflects of the market equilibrium condition. Production costs of each sector in the model include labor costs by type of labor, energy costs, capital costs and the costs of intermediate inputs. The sector's technological constraint describes the production technology of each sector. It provides information on how many of different

units of labor, energy, capital and commodities, are necessary for the production of one unit of the sectoral output.

The production technology of the sector is represented by the nested Constant Elasticity of Substitution (CES) functions. Nested CES function is quite flexible and allows for different assumptions about the degree of substitutability between the production inputs. Inputs which are easier to substitute with one another are put into the same nest. Inputs which are more difficult to substitute in the production process are put into different nests. The degree of substitutability is the lowest on top of the nested CES function and the highest at the bottom of it. All production inputs in the CES tree have a certain degree of substitutability between each other and it depends on their relative position in the tree. In accordance with their production technology, sectors have substitution possibilities between different intermediate inputs and production factors.

Time dynamics

The model is a dynamic, recursive over time model. A recursive dynamic is a structure composed of a sequence of several temporary equilibriums. The first equilibrium in the sequence is given by the benchmark year. In each time period, the model is solved for an equilibrium given the exogenous conditions assumed for that particular period. The equilibriums are connected to each other through physical and human capital accumulation. Thus, the endogenous determination of investment behavior of households and firms is essential for the dynamic part of the model.

Because of the elaborate regional dimension of the model, it is quite difficult to implement full dynamics. This would drastically increase the number of equations in the model (the number of equations of the static model should be multiplied by the number of time periods) and make it non-manageable. Instead, we use the recursive-dynamic framework which allows for the model size to be manageable.

Sales

Domestic regional sales of services are equal to the production of a service sector in the region. In the model we make an assumption that services are not traded between the countries. This is a restrictive assumption, which is justified by the absence of the data on inter-regional trade in services at the country level.

Domestic regional sales of each type of commodities are composed of the commodities and services produced by the domestic sectors, those imported from other regions and those imported from the rest of the world. According to the Armington assumption, the same type of commodity produced by the domestic sectors, imported from the other regions or imported from the rest of the world has different specifications and, hence, cannot be treated as a homogenous good. Domestic consumers have different preferences for these specifications and can substitute between them in case the relative prices of the specifications change. The substitution possibilities between these commodities specifications are captured by a CES function that varies between the types of commodities. This means that the shares in which commodity are bought from the domestic producers, from other regions and from the rest of the world are determined by the relative producer prices of the commodity, transport and trade costs.

Savings and investment

The model incorporates the representation of investment and savings decisions of the economic agents. Savings in the economy are made by firms, households, government and the rest of the world. The total savings accumulated at each period of time are invested into accumulation of the sector-specific physical capital, which is not mobile between the sectors.

Governments

The model incorporates the representation of a national government. The government sector collects taxes, pays subsidies and makes transfers to households, production sectors and to the rest of the world. Tax revenues are shared by the national and regional governments according to the certain rates determined from the base year data. The national government consumes a number of commodities and services, where the optimal governmental demand is determined according to the maximization of the governmental consumption utility function. We use a Cobb-Douglas utility function in the model. Its maximization results in the demand rules, which says that the expenditure share of different commodities and services purchases by the government stay constant over time. The model incorporates the governmental budget constraint. According to this constraint the total governmental tax revenues are spent on subsidies, transfers, governmental savings and consumption. There are transfers between the regional and national governments.

Transport & trade

The transport sector is highly disaggregated in the model. Railway, road transport, pipeline transport, inland waterway and maritime transport as well as airline and auxiliary transport services are considered as separate sectors. Consumers use transport services from publicly produced transport or can consume their own transport. Transport cost for passengers are attributed to the consumer budget and the time value is attributed to the labour supply.

Trade between regions requires the consumption of trade inputs, in the form of trade margins. These are produced by a mix of the transport and wholesale sectors. Increased trade, increases the demand for trade margins and hence for transport. Taxes and road charges increases the price of trade and has economy wide effects on the prices of intermediary and consumption goods.

3. Applied case: Iron Rhine connection

3.1 Case description

The Iron Rhine connection is an old railway connection between the port of Antwerp in Belgium and the German Ruhr area. Belgium asked the Netherlands in 1998 to reactivate the railway, referring to the increased freight transport between Antwerp and the German Hinterland. The current route to Germany, the Montzenroute, is about 50 kilometers longer than the Iron Rhine and is more hilly, which restrains the use of heavy freight trains.

3.2 Simulation setup

Our simulation is based on a limited set of key numbers from the social cost-benefit analysis of the Iron Rhine connection (2009), performed with the TRANSTOOLS network model. Our approach however is largely theoretical and makes no reference to the conclusions of this particular study. The simulation presents a test-case for the model, but is not meant for policy analysis.

We consider the improvement of one rail link, between the agglomeration of Antwerp (BE211) and the region of Dortmund (DEA). From the social cost-benefit analysis study we take the decrease in transport costs from one of the main bi-regional links between the two agglomerations. The transport cost for freight by railway decreases by 22% in this particular case (Table 1)

Table 1: changes in transport cost

Transport cost (euro/ton)	
Basecase	Simulation
6.19	5.07
Modal shares (%)	
Road	64.39
Rail	8.1
IWW	27.51

This implies a decrease in total transport costs on all freight passing through the port. The total transport savings are associated with imports and exports of products from the Ruhr area, which enter to the port of Antwerp. We calculate the total transport savings and associated these to the particular products as a decrease in price of imports and an increase in the export price (Table 2). The total transport savings are 9.18 million euros.

Table 2: Transport savings associated with export and import of products (million euros)

Imports	Tcost	%Rail	OthModes	TcostRail	Tsavings	%Total
AgrMining	1857	0.081	1708	148.57	1.96	0.397
Intermediates	1563	0.081	1438	125.08	1.65	0.334
Fuels&Chemicals	864	0.081	796	69.14	0.91	0.185
FinishedGoods/Vehicles	390	0.081	359	31.23	0.41	0.083

Exports	Tcost	%Rail	OthModes	TcostRail	Tsavings	%Total
AgrMining	0	0.081	0.00	0.00	0.00	0.000
Intermediates	1807	0.081	1662	144.56	1.82	0.427
Fuels&Chemicals	1532	0.081	1409	122.57	1.54	0.362
FinishedGoods/Vehicles	889	0.081	817.7	71.11	0.89	0.210

3.3 Results

In Table 3 we present the results on welfare and regional GDP for Belgium, Netherlands and Germany, with the port area and the Ruhr area distinguished separately. We measure welfare by equivalent variation, calculated directly from household utility.

The total welfare gain from the improved railway connection amounts to 10.72 million euros, which is largely associated to the Ruhr Area. Regional GDP of the port and the Ruhr area increases, however for the rest of Germany the effect is negative. For Belgium, the main benefit is located in the port region (agglomeration of Antwerp). The regional GDP of Antwerp increases from the improved market access and the increased activity of the port, in the rest of Belgium the effect is close to nil. Surprisingly, the rest of Belgium and the Netherlands experience a positive welfare effect too. This is because of cheaper imports supplied from the German Ruhr area.

Table 3 Welfare

	Welfare	Regional GDP
Rest Germany	0.014	-2.182
Ruhr area	8.803	4.459
Rest Belgium	0.592	0.034
Antwerp Port	0.319	1.902
Netherlands	0.996	0.135
Total	10.72	4.35

The disaggregated trade results are available in Table 4. Sectors are aggregated to goods and services. The disaggregated results show how the improved railway connection benefits both the Ruhr area and the port. Production from the rest of Germany partially displaces to the Ruhr area.

Table 4: Disaggregated trade results (million euros)

		DE	BE	Antwerp	Ruhr area	NL	Total
Regional demand	Goods	-12.34	-0.90	0.06	11.63	-0.02	-1.57
Production by sector	Goods	-7.95	0.07	-0.05	17.71	0.63	10.42
Exports of products to EU	Goods	0.41	0.37	0.00	5.90	0.68	7.37
Exports of products to ROW	Goods	0.36	0.10	0.00	7.10	0.36	7.92
Imports of products from EU	Goods	-2.25	-0.05	-0.01	1.85	-0.04	-0.49
Imports of products from ROW	Goods	-3.86	-0.28	-0.02	3.67	-0.58	-1.07
Imports of products from other regions	Goods	0.80	-0.38	0.05	0.69	0.33	1.49

		DE	BE	Antwerp	Ruhr area	NL	Total
Regional demand	Services	-7.79	-0.39	1.44	7.99	-0.11	1.14
Production by sector	Services	1.29	-0.01	1.45	-1.60	-0.01	1.12
Exports of products to EU	Services	0.22	-0.11	0.78	0.00	0.05	0.94
Exports of products to ROW	Services	0.15	-0.10	1.12	-0.02	0.05	1.19
Imports of products from EU	Services	-0.14	0.02	0.21	0.31	0.00	0.41
Imports of products from ROW	Services	-0.08	0.01	0.10	0.22	0.00	0.26
Imports of products from other regions	Services	-6.31	-0.45	0.62	5.35	-0.13	-0.92

4. Conclusion

The TIGER model is a new spatial computable general equilibrium model constructed on the level of the Benelux, based on the methodology of the RAEM and ISEEM models. The model is constructed as a flexible tool for policy analysis and as a tool for cost-benefit analysis of infrastructure projects. The paper contains a limited application of the model, inspired by the Iron Rhine connection.

The preliminary results of the model are interesting, as they show that the Ruhr area has a large benefit from the railway connection, which is not clear from the perspective of a network model. In terms of gross production, the TIGER model predicts an increase in both the regional GDP of the port and the hinterland.

On the country level, the main benefit is for Germany, however both Belgium and the Netherlands have additional secondary benefits as imports from the Ruhr area become cheaper.

Further work with the model will be focused on validating the model results through improved sensitivity analysis and performing more policy related runs.

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