# A LONG-TERM REGIONAL CGE MODEL FOCUSED ON TRANSPORT ISSUES IN BELGIUM[1]

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## ABSTRACT

The paper describes the set-up of a regional computable general equilibrium model for Belgium and its three regions. The CGE approach allows to model the two-way interactions between transport and the economy in general. The aim is determine both the implications of economic developments on transport use, and the indirect impacts of changes in the transport sector on the economic system and the location of activities, taking into account agglomeration effects. The model will be used to calculated the full welfare impacts of policy changes, taking into account the impacts on all economic agents and not only on the transport sector. The inclusion of different household groups makes it possible to determine the distributional impacts of policies.

*Keywords: Regional computable general equilibrium model, Agglomeration effects, Transport externalities, Distributional analysis*

## INTRODUCTION

The paper describes part of a new modelling tool that is currently being developed in the framework of the LIMOBEL project in order to analyse the long-run mobility impacts of policy packages in Belgium. In the LIMOBEL modelling tool three existing models are being developed further and linked to each other (De Vlieger et al., 2010). The first model is the PLANET2 model, a model for long-term transport projections. The second model is the Nodus model, which is being extended in order to cover both passenger and freight transport. E-motion, the third model, is an environmental impact assessment model that consists of an emission model for road, railway and shipping traffic and of an environmental cost model.

In the long-term transport projection model we want to relax the assumption that the evolution of the economy is unaffected by changes in the transport sector. For this a recursively dynamic computable general equilibrium (CGE) model for the Belgian economy

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and its three regions is being developed. The model is an extension of the model presented in Mayeres (1999) and incorporates elements of New Economic Geography[2]. The aim is to model both the implications of economic developments on transport use, and the indirect impacts of changes in the transport sector on the economic system. The CGE approach allows for an explicit calculation of the full welfare impacts of policy changes, taking into account the impacts on all economic agents and not only on the transport sector. The discussion in this paper focuses on the features of the static part of the CGE model. The first part presents the structure of the model. Next, we discuss the data that are required for the set-up of the model.

# THE STRUCTURE OF THE CGE MODEL

The CGE model incorporates the following economic agents: different households groups, the domestic production sectors, the trade sectors, the federal government and the regional governments and the foreign sector. The model is programmed in GAMS and is solved using the PATH solver. The first four sections of this paper discuss the modelling approach for the households, the domestic production sectors, the trade sectors and the Belgian governments. Next, the institutional setting of the labour market is presented. This is followed by the modelling of the domestic and international trade levels. The last two sections treat the savings and investment decisions and the market equilibrium conditions.

## The households

The CGE model includes different household groups (per region), characterised each by a nested CES utility function which they maximize subject to a monetary budget and a time budget constraint. Based on the Belgian Household Budget Survey (Vandresse, 2009), a number of representative household groups are selected. The groups are defined in terms of three criteria: the region (Brussels, Flanders, Wallonia), the education level (high and low skilled)[3] and employment status of the head of the household (employed, unemployed, not participating in the labour market). The inclusion of several household groups allows for a distributional analysis of policies. Each household has a fixed endowment of capital and time.

### *The household utility function*

The utility function of each household belonging to a group consists of three components:

- The first component is the direct utility derived from the consumption of commodities and time use.
- The second and third components of the utility function reflect the impact of emissions and transport accidents on utility. Both are assumed to affect the household's utility negatively. It is assumed that the household's preferences are separable in the emissions and accidents. Moreover, each household is taken to

[2] Other models belonging to the same tradition are CGEurope (Bröcker et al., 2004), RAEM (Thissen, 2004) and ISEEM (Heyndrickx et al., 2009) and REMI (2007).
[3] The low skilled group includes all people with an education up to a secondary school degree

ignore its own impact on emissions and accidents. It considers itself to be infinitely small compared to society, leading to a classic externality problem.

The first component of the utility function is described by a nested utility function. Figure 1 presents the nesting structure[4]. The utility function is defined over the so-called excess quantities that are consumed, i.e. total consumption from which a basic consumption level is subtracted. This way, non-unitary income elasticities are allowed for.

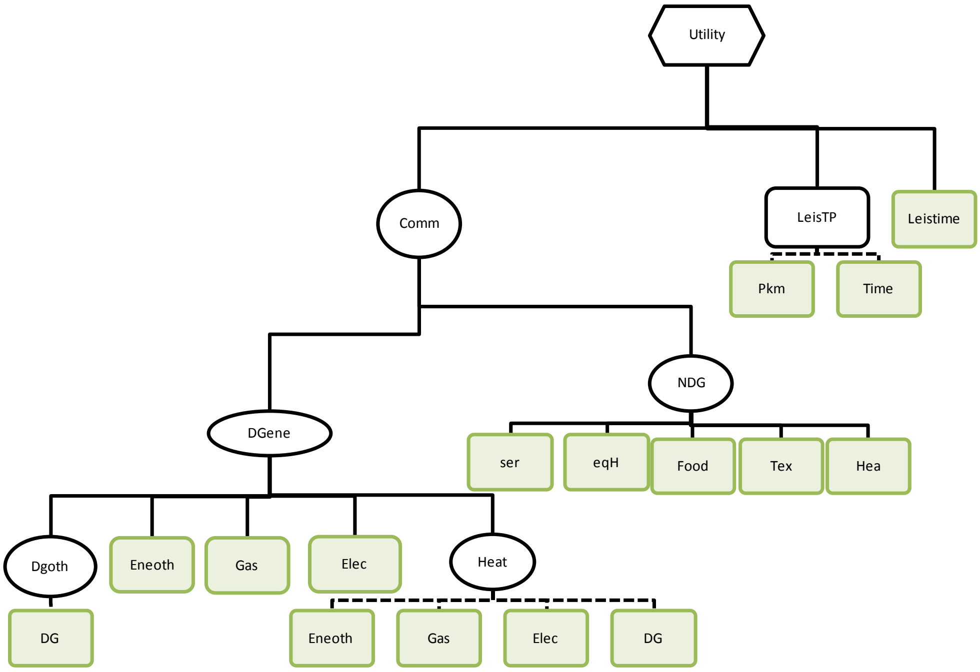



Figure 1: The nesting structure of the first component of the household utility function

The utility function in Figure 1 is defined over the household's excess consumption of two types of durable goods services, three energy goods, five types of non-durable goods, leisure transport and leisure time. Most utility components are specified as Modified Constant Elasticity of Substitution (MCES) functions (Keller, 1976) of the associated utility components at the lower level. At the top level the first component of the utility function is a MCES function of leisure time (leistime), leisure transport (LeisTP) and a composite of the other goods and services (Comm). Leisure transport is a Leontief function of passenger km and transport time. The composite commodity is a MCES function of the composite of non-durable goods (NDG) and the composite of durable goods and energy (DGene). The non-durable goods composite is a MCES function of five types of non-durable goods: health related goods and services (Hea), textile and shoes (Tex), food, drink and tobacco (Food), household equipment (eqH) and education, communication, culture and others (ser).

The durable goods and energy composite is a MCES function of the consumption of 2 types of durable goods services (Major appliances (Heat) and Other durable goods (DGoth), comprising mainly housing) and of three energy goods (Gas, Electricity and Other energy).

[4] In all figures dotted Lines refer to a Leontief function, while solid Lines refer to a MCES or CES function.

The consumption of the durable goods services requires the input of the durable goods themselves, and of a minimum level of energy goods, as modelled by a Leontief function. This way, it is captured that the price of the energy goods may influence the consumption of durable goods. Households can choose to consume more than the minimum amount of energy that is required for the operation of the durable goods. The supplementary energy consumption is included in the energy components of the utility function.

### *The constraints on the utility maximisation problem*

The income constraint states that the spending on the different commodities cannot exceed household income. Income consists of non-labour income and labour income minus the commuting costs. An exogenous share of this income is saved. From this income the spending on school transport is also subtracted.

It is assumed that commuting journeys are complementary to labour supply. The production-attraction matrix (P-A matrix) for commuting is determined endogenously in the model (see below). The average monetary cost per commuting journey between the different production and attraction regions is taken from the household transport decision process, which is discussed below.

The number of school journeys follows from the number of students in the household. The P-A matrix for school journeys is exogenous. As in the case of the commuting journeys, the average monetary cost per school journey between the different regions is taken from the household transport choice process.

The time constraint ensures that the sum of labour time (including commuting time), school time (including school transport time), leisure time and leisure transport time does not exceed the total time available.

The income and the time constraint are combined to arrive at the generalized income constraint, which is defined for each household type:

> *Generalised disposable income*
> *= net time income + net income from the fixed factor and land endowment*
> *+ net capital income + net transfers received from abroad*
> *+ unemployment benefits + other government transfers*
> *- saving (defined as a percentage of the previous income components)*
> *- spending on school transport*
> *- spending on basic consumption of durable goods, non-durable goods, energy, leisure transport and leisure*

In this expression net time income per household is determined as the product of the corrected net wage and total available time from which the school time (including school transport time) is subtracted.

*Net time income = corrected net hourly wage*
** (total time in hours – school time in hours – school transport time in hours)*

The corrected net wage is calculated as follows:

*Corrected net hourly wage = (gross hourly wage – commuting cost per working hour)/(1 – commuting time per working hour)*(1 – average labour tax rate)*

Generalised spending on the excess quantities of commodities and leisure cannot exceed generalised disposable income. In order to determine generalised spending, the excess quantities are multiplied by generalised prices. The generalised price of leisure transport trips includes both the monetary costs and the time costs (calculated as the product of the average time per trip and the corrected net wage). The generalised price of leisure equals the corrected net wage.

### *The household transport decisions*

The household transport decisions are determined per trip purpose (commuting, school transport and leisure transport) and per production-attraction or origin-destination pair. In each of these cases the households are assumed to minimize their generalized transport costs subject to the household production technology for transport. The transport production function is a nested function as presented in Figure 2. The elements of the production function are passenger km or vehicle km and travel time

- by the different modes: car solo, car pool, motorcycle, rail, bus/tram/metro/, on foot/by bicycle and air,
- per time period: peak and off-peak,
- per location: in Belgium and abroad.

For car and motorcycle transport the costs per vehicle km are obtained from a cost minimization problem. The model allows for vehicle km to be produced using different vehicle types, each requiring inputs of car services, fuel, transport maintenance and insurance. The structure of the nested production function is given in Figure 3. The current model version only considers an average vehicle.

The average monetary costs and the average time per trip which result from these cost minimization problems are an input in the utility maximization problem of the households:

- the price of leisure transport is given by the average generalized cost of the trips for leisure purposes;
- the generalized budget constraint subtracts the time and monetary costs of commuting and school trip from the available budget.

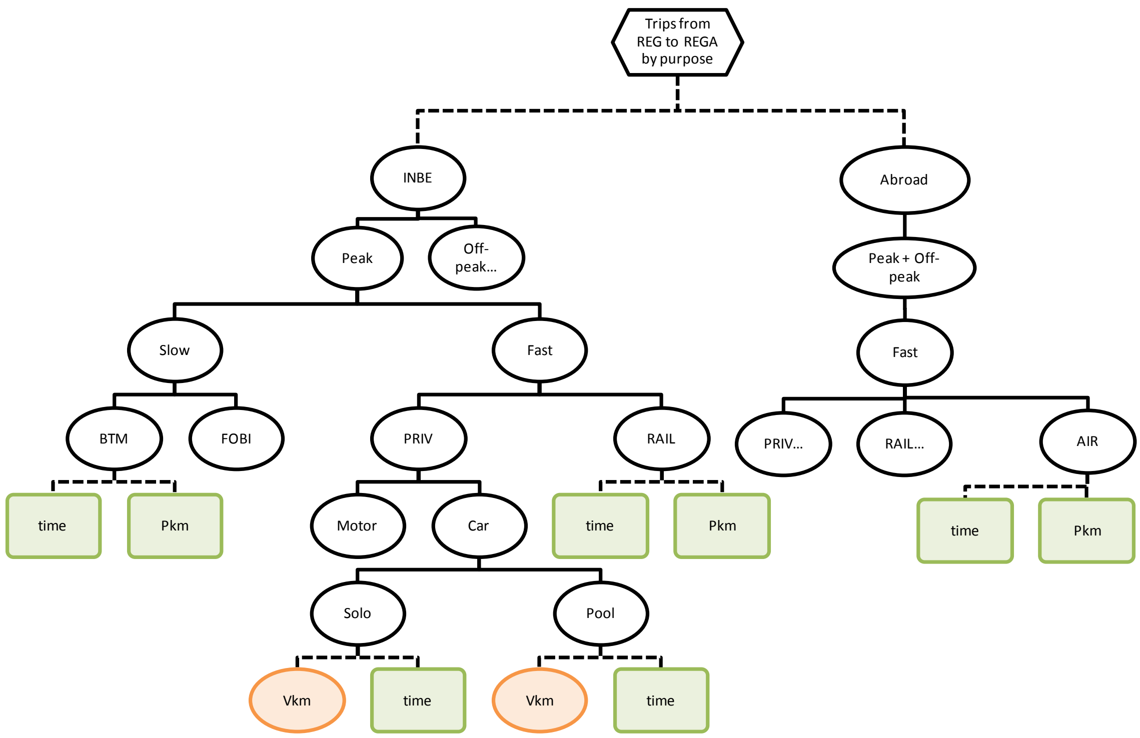



Figure 2: The production function for household transport (defined by household type, trip purposes and zone pair)

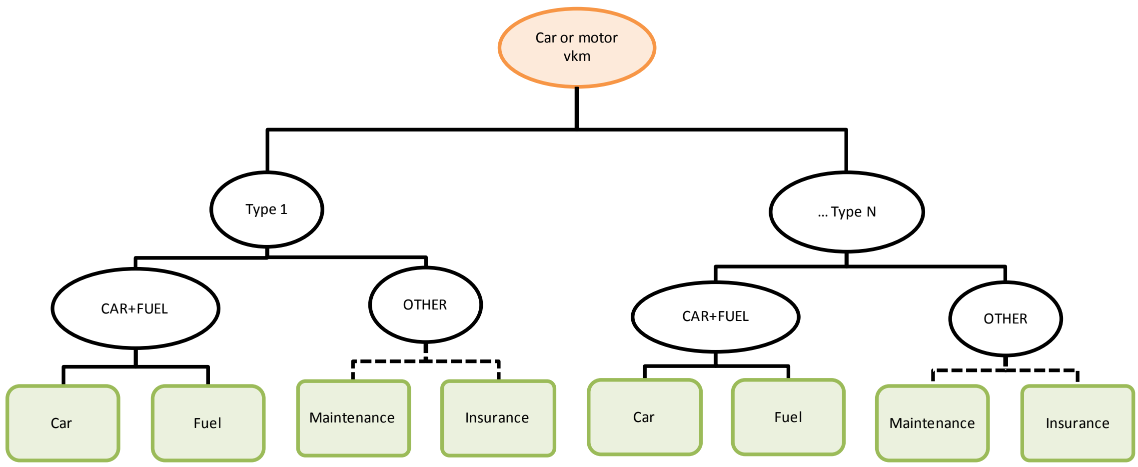



Figure 3: The production function for household car and motor vehicle km (defined by household type)

### *The labour supply decision*

In order to determine the labour supply of the households a distinction is made between the choice at the intensive margin (the number of hours) and the participation decision at extensive margin (determining the labour force). Following Kleven en Kreiner (2006) and Boeters and van Leeuwen (2008) the labour supply decision is modelled as a two-step process which is solved backwards. First, the household determines the optimal number of working hours assuming that it participates on the labour market. Next, it compares the outcome with the fixed costs of working, which may include, for example, the difficulties in organising family life, etc. Households are assumed to be heterogeneous in terms of these fixed costs. On the basis of this comparison they decide to participate or not.

Due to the characteristics of the dataset used for calibrating the model, the participation decision is modelled only for the head of the household. If other members of the participating household also supply labour, this is captured in the decision on the number of hours.

**Labour supply: hours of work**

Given that the head of the household participates on the labour market, the hours of work are determined by maximizing the household utility function as presented in Figure 1, subject to the generalised budget constraint. The hours of work (per participating household) are calculated as follows:

> *Hours of work = (total time – school time (including school transport time) – leisure time – leisure transport time)/(1+commuting time per hour of work)*.

Participating households for which the head of the household is low (high) skilled are assumed to supply only low (high) skilled labour.

In the dataset for the base year households whose head decides not to participate, also supply some labour. In the model simulations it is assumed that the labour supply per household remains constant for these households. Households with a non-participating head of household supply a mix of high and low skilled labour.

**Labour supply: participation**

For the choice of labour supply on the extensive margin, each household faces a random cost of supplying labour, which is assumed to be uniformly distributed with density *h* over some interval [$cost_{min}$, $cost_{max}$]. Before entering the labour market, each household in domestic region *reg* of skill type *slab*, weighs this cost against the expected gain from employment $U_L$:

$$U_L(reg, slab) = (1\text{-}UNRATE(reg,slab)).U_E(reg,slab) + UNRATE(reg,slab).U_U(reg,slab)$$

*UNRATE* is the unemployment rate per skill type in region *reg*. $U_E$ is the utility when employed and $U_U$ is the utility when unemployed.

Given *h*, the number of participating households *PART(reg,slab)* adjusts to changes in utility according to:

$$PART(reg,slab) = bpart(reg,slab) + h.(U_L - bu_L)$$

*bpart* and $bu_L$ refer to the initial number of participating households and the initial expected gain from employment.

The number of households in region *reg* of skill type *slab* that are involuntarily unemployed is obtained as follows:

$$UNEMP(reg,slab)$$
$$= (PART(reg,slab)*LABS(reg,slab) - LD(reg,slab) - INACT(reg,slab)$$
$$*blabs\_inact(reg,slab))/ LABS(Breg,slab)$$

*LABS(reg,slab)* refers to the hours of work per participating household and *LD(reg,slab)* gives the total labour demand for skill type *slab* from region *reg*. *INACT* stands for the number of non-participating households and *blabs_inact* is the hours of works supplied by these households in the reference equilibrium.

## The production sectors

The production side of the model considers 25 sectors (per region), 8 of which are transport sectors (sectors 18 to 25). An overview is given in Table 1, which also presents the correspondence with the sectors of the Supply and Use Tables.

### *The competitive environment*

The model distinguishes between two types of competitive environment in which the firms operate: perfect competition (PC) and monopolistic competition (MC).

For sectors 1 and 2 perfect competition is assumed to hold. In the other sectors, the producers in each region operate on monopolistically competitive markets[5] and choose the levels of output to maximize profits. Their production technology is characterised by increasing returns to scale. Each regional sector with monopolistic competition contains a certain number of firms, producing slightly differentiated goods and services. Since statistical data describing the production process of the individual firms in the sector are lacking, all firms are assumed to be homogenous and to have the same production technology, the same output size and the same fixed production costs.

[5] In a later version of the model three different types of competitive environment will be considered: perfect competition, monopolistic competition and regulated monopoly.

Table 1: The LIMOBEL production sectors

| Sector no. | Description | Supply and Use Tables code |
|---|---|---|
| NON-TRANSPORT SECTORS | | |
| 1 | Agriculture, forestry, fisheries | 01,02,05 |
| 2 | Cokes, Refined Oil, Nuclear Fuels | 23 |
| 3 | Ferrous and non - ferrous metals | 27 |
| 4 | Electricity | 40 |
| 5 | Raw Materials, building materials | 14,26 |
| 6 | Chemical Products, pharmaceutics | 24 |
| 7 | Other energy intensive industries (paper, plastics, metal products) | 21,25,28 |
| 8 | Electrical goods | 30,31,32,33 |
| 9 | Transport equipment | 34,35 |
| 10 | Machinery | 29 |
| 11 | Consumer goods | 17,18,19,20,21,22,36,37 |
| 12 | Food, drinks, tobacco | 15,16 |
| 13 | Construction | 45 |
| 14 | Water supply | 41 |
| 15 | Financial services | 65,66,67 |
| 16 | Market Services | 50,51,52,55,63,64,70,71,72,73,74,85,91,92,93,95 |
| 17 | Government Services | 75,80,90 |
| TRANSPORT SECTORS | | |
| 18 | Rail | 60A1 |
| 19 | Road Freight (Heavy Duty) | 60C1 + own account |
| 20 | Road Freight (Light Duty) | 60C1 + own account |
| 21 | Bus/tram/metro | 60B3 |
| 22 | Other road Passenger Transport | 60B1 |
| 23 | Maritime transport | 61A1 |
| 24 | Inland navigation | 61B1 |
| 25 | Air transport | 62A1 |

The cost structure of each monopolistically competitive firm consists of variable and fixed costs. Fixed costs are related to its initial establishment in the sector and consist of the costs of fixed capital and labour inputs. Each firm produces one particular variety of the commodity. It sets its price by charging a constant mark-up over marginal costs in order to cover its fixed costs. The equilibrium number of firms is determined by the assumption of free entry/exit which leads to zero profits. The number of firms is therefore endogenous.

At this stage we have opted to integrate imperfect competition in a simple way by considering monopolistically competitive sectors with constant mark-ups over marginal costs. More complex modelling approaches could be envisaged (see Willenbockel, 1994). In general, the price/cost margins depend on the type of oligopolistic regime, the relative market shares and the competitive environment. In a later stage, the competitive setting of some sectors could be changed to take into account strategic interactions between firms belonging to a sector.

The introduction of imperfect competition has implications for the modelling of demand by firms, households and the government. The model integrates “love of variety”; all consumers may benefit from the expansion of varieties and can achieve efficiency gains in the volume and costs of their consumption. As such, agglomeration effects are introduced in the CGE model, with reference to the New Economic Geography literature (see below).

### *The production functions*

The variable inputs for each sector (by region) are determined according to a nested production function, with the following inputs: capital, two types of labour (low and high skilled), various energy inputs and a number of intermediate inputs. The general nesting structure that is used for all sectors is presented in Figure 4.

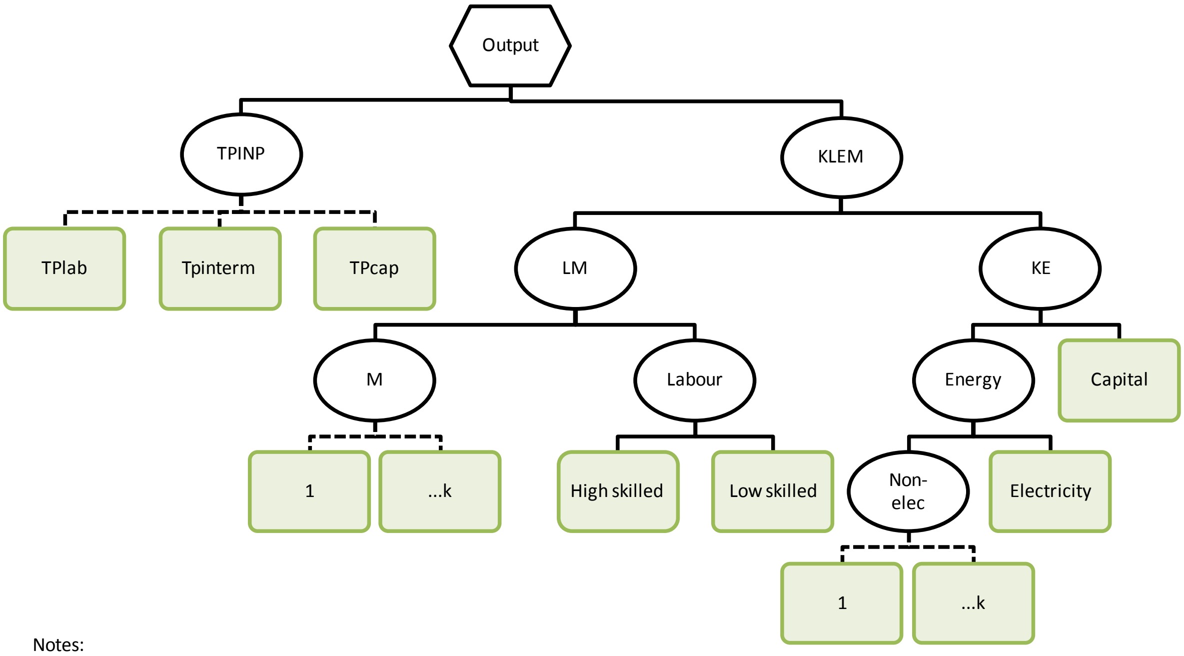
The upper nest is relevant only for the transport sectors. At this level the producers choose the transport inputs (TPINP), and the KLEM composite of capital, labour, energy and materials. This choice is modelled as a CES function.

The transport inputs composite is a Leontief function of transport capital (TPcap)[7], transport labour (TPlab; low-skilled labour) and intermediate goods (TPinterm). For road freight transport the input of transport labour is not included at this stage. It is modelled together with the use of these transport services by the trade sectors. This allows taking into account the difference in speed during the peak and off-peak period.

The capital-labour-energy-intermediates (KLEM) composite is the result of the choice between labour and intermediates (LM) on the one hand and capital and energy (KE) on the other hand, according to a CES production function. At the next level the labour-intermediates composite is a CES function of the intermediates composite (M) and the labour composite. The input levels of the different intermediate inputs are determined according to a Leontief production function. In the labour composite the choice between low skilled and high skilled labour is modelled by a CES production function. The cost of labour equals the sum of the wage including the taxes paid by the employer and the search costs related to vacancies (see below).

The capital energy composite is a CES function of capital and energy inputs. In each period, capital is assumed to be sector specific. At the next level a CES function describes the choice between the input of electricity and of the non-electric energy composite. The last component is a Leontief function of various energy inputs.

[7] In the case of public transport, the input of transport capital is determined mainly by the level of public transport demand in the peak period. This could be taken into account by making a distinction between peak and off-peak public transport sectors, with transport capital entering only the production function of peak public transport.




Notes:
-TPINP: only for transport sectors (sectors 18 to 24)
-For road freight (sector 19), Tp labour is left out of the transport nest

Figure 4: The general nested production technology for all sectors (by sector and region)

## The trade sectors

The trade sectors are auxiliary sectors that combine the commodities from the regions of origin with freight transport in order to deliver the commodities to the regions of destination. The number of trade sectors equals the number of zone pairs times the number of commodities. The zone pairs considered in the CGE model are presented in Table 2. The shaded zone pairs refer to trade between the Belgian regions, while the others concern international trade, with a distinction between trade relations with other the countries of the European Union and trade relations with the rest of the world.

Table 2: The zone pairs for which trade relations are modelled

| | | Region of destination | | | | |
|---|---|---|---|---|---|---|
| | | Brussels | Flanders | Wallonia | EU | ROW |
| Region of origin | Brussels | X | X | X | X | X |
| | Flanders | X | X | X | X | X |
| | Wallonia | X | X | X | X | X |
| | EU | X | X | X | | |
| | ROW | X | X | X | | |

The trade sectors minimize the costs of ensuring a given level of trade subject to the trade production technology. The determination of the trade levels is discussed below. The trade production technology is represented by a nested structure (Figure 5). At the top level the trade of a commodity between two regions is a Leontief function of the commodity in the region of origin and the freight transport services composite. The input of freight transport services is not required for the trade in services, electricity and water.

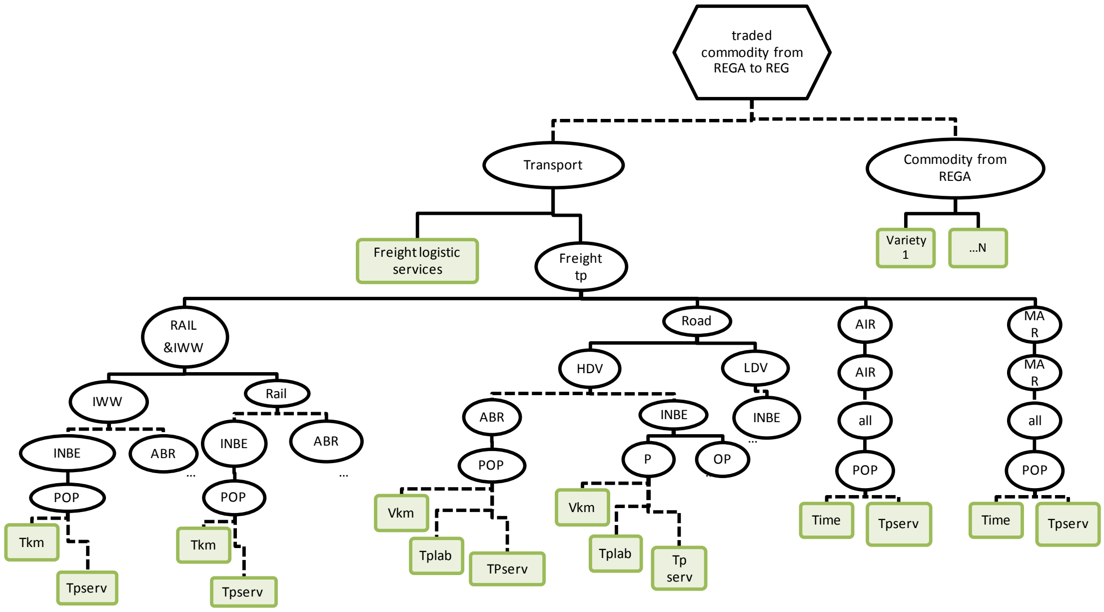
The agents in the region of destination who use or consume goods (households, government, firms, rest of the world) have widely differentiated preferences with respect to the varieties of the commodities produced by the firms in the monopolistically competitive sectors. They therefore purchase output of all the firms in the sector in the region of origin. The input demand for a commodity in the trade production function is modelled as a Dixit-Stiglitz aggregate of the different varieties. The "love-of-variety" is thus introduced at this stage of the model. The functional form of the function is equivalent to the CES function, making it a concave function which positively depends on the number of firms (varieties) in the region of origin. This modelling approach is used only for the domestic regions of origin.

For the commodities that are imported, the price in foreign currency is exogenously fixed. The price in domestic currency is calculated using a fixed exchange rate.

The freight transport services composite is a CES function of freight logistic services and freight transport. This approach allows capturing that an increase in transport costs may increase the demand for logistic services and vice versa. Freight transport is a nested CES function of transport in different locations, by different modes and in different periods. The inputs at the lowest level include both physical inputs (ton km) as time related inputs. The last category of inputs depends on the speed of the different modes. For road transport in the peak and the off-peak period the speed can be made dependent on total traffic levels.

A fall in road speed increases the amount of labour (TPlab; low-skilled labour) that is required for transport by HDV and LDV and also leads to more input of logistic services (TPserv). For the non-road modes the time related inputs only refer to the additional logistic services that are required if transport speed falls. The transport labour itself is included in the production function of these freight transport sectors (see Figure 4).

The price of the traded commodities is a weighted average of the prices of the freight transport service inputs and the monopolistic competition price of the commodities in the region of origin.




Notation: INBE: in Belgium; ABR: abroad; P: peak period; OP: off-peak period; POP: peak+off-peak period; IWW: inland navigation; MAR: maritime transport, HDV: heavy duty vehicle; LDV: light duty vehicle

Figure 5: The production technology of the trade sectors (by zone pair and commodity)

## The governments

Given the institutional setting of Belgium, five governments are included in the model: the Brussels Capital region, the Flemish region, the Walloon region, the French community and the federal government. The last government is broadly defined and includes all governments which do not belong to the previous categories. It includes, amongst others, the federal government and the municipalities. This approach is due to data availability.

Decisions made by one government level may have an impact on the other government levels. The model includes the main policy instruments. The policy changes that are simulated focus on the transport instruments (transport taxes and subsidies, transport regulation, infrastructure measures). However, if additional revenues are generated, the instruments that are used to recycle this revenue may be transport as well as more general policy instruments such as labour income taxation or social security transfers. A similar comment holds if additional revenues are required to finance the transport policy changes.

We consecutively treat the different government taxes, charges and subsidies, the government transfers and the modelling approach for government consumption.

### *Government taxes, charges and subsidies*

Each government receives two types of income: taxes levied on the economic agents within the regions under its jurisdiction and income from intergovernmental transfers. Not all governments collect tax income. More particularly, the communities do not have the power to levy taxes. The federal government is responsible for collecting the main part of the tax revenues. This includes the full income tax and social security contributions, as well as a large share of the other taxes.

The revenue raising instruments include: social security payroll taxes, labour income taxes, taxes on production, capital income taxes and consumption taxes (VAT, excises taxes and other taxes and charges on consumption). All taxes on consumption are modelled as ad valorem taxes, in order to ensure homogeneity of the model.

For some taxes the tax rates may differ across regions. The different governments get a given share of the total tax revenue from each type of tax.

Subsidies are introduced in the model as negative taxes. They are treated in a similar way as taxes. The model includes subsidies on production and consumption.

### *Government transfers*

The governments transfer income to the households and to the other governments. For the transfers to the households a distinction is made between the unemployment benefits and the “other transfers”. The “other transfers” are assumed to remain constant in real terms for each household type. The total unemployment benefits that are paid by the governments depend on the average wage level in the region and on the level of unemployment within each region. The unemployment benefits only partially compensate the loss in the real wage. The degree of compensation is exogenously fixed.

In the current version of the model the transfers between the Belgian governments are taken to remain constant in real terms. Alternative rules could be introduced to determine these intergovernmental transfers, consistent with current legislation on intergovernmental transfers. The net transfers paid to the EU and the ROW are constant.

### *Government consumption*

Each government is modelled as if it were a single consumer who maximizes a utility function subject to a budget constraint. This formulation allows constructing an equal yield measure, that can be used in balanced budget incidence simulations. In such exercises it is assumed that the government spending on commodities at new equilibrium prices is such that the government has the same utility level as in the benchmark equilibrium.

The consumption budget of each Belgian government is obtained as follows:

> *Government budget = total tax revenues – total subsidies – total unemployment benefits – total "other transfers" to the households + net transfers received from the other Belgian governments – net transfers paid to the EU and the ROW + government deficit.*

Government spending on the various commodities is modelled in two stages. In the first stage each region receives a fixed part of the government spending. In the second stage, the consumption budget allocated to each region is assigned to the different regional commodities according to a Cobb-Douglas function.

## The labour market

The labour market is modelled for two skill types (low and high skilled). Each region has an endogenous labour supply. Involuntary unemployment is modelled through wage bargaining between employers and employees at the regional level. At the heart of the interregional commuting block are three basic equations, which can be understood as a spatial interpretation of Pissarides' theory of search unemployment (Pissarides, 2000). The advantage of this approach is that it allows to model commuting flows between the three regions endogenously.

### *The matching function*

It is assumed that the unemployed in one region search for a job in every region. Vacancies and job seekers are matched through an imperfect process, the efficiency of which diminishes with distance – captured by the generalised commuting costs between the different regions. The matching function for skill type *slab* is:

> *NM(reg,rega,slab)*
> *= aM(reg,rega,slab)*NV(rega,slab)**alphaM(reg,rega,slab)*
> **(UNEMPL(reg,slab)**(1-alphaM(reg,rega,slab))*
> **exp(-betaM(reg,rega,slab)*COMMC(reg,rega,slab))*

It is defined for domestic pairs of regions only. The number of matches (*NM*) between a vacancy in region *rega* and unemployment in region *reg*, depends on the number of vacancies (*NV*) within the region of destination and the unemployment (*UNEMPL*) within the region of origin, but decreases exponentially with the generalized commuting costs (*COMMC*) between the regions. *alphaM* and *betaM* are parameters of the matching function. The scaling parameters *aM* subsume all other influences than generalised commuting costs on the matching process, such as the language barrier.

From this one can derive the probability that a vacancy in region *rega* is filled:

*QR(rega,slab) = SUM(reg,NM(reg,rega,slab))/NV(rega,slab)*

### *The job creation condition*

When deciding on the level of employment, firms take into account that each period jobs are destroyed at an exogenous rate *sep*. When a job is opened, the firm incurs a cost *υ* of posting a vacancy. In the case of a simple production function with labour as the only input, the problem of the firm then becomes to maximize a perpetual stream of net profit flows:

$$Max \quad \Pi = \sum_{s=t}^{\infty} \left( \frac{1}{1+r} \right)^{s-t} \left[ p.\ Y\ \ L\ \ - \upsilon.V\ \ - p_l.L \right]$$
$$s.t. \quad \dot{V} = QR.V - sep.L$$

This is a dynamic optimisation problem, with labour demand (*L*) as the stock variable, and vacancies (*V*) as the flow variable. *Y(L)* is the gross production function. $p_l$ is the price of labour, *r* is the interest rate and *p* is the output price.

The job creation condition is then:

$$Y'\ \ L\ \ = \frac{p_l}{p} + \frac{r + sep\ \ \upsilon}{QR}$$

From the equation, it is clear that the value of marginal product of labour exceeds the real wage. The reason is that a filled job, just by being filled, saves the firm the trouble of looking for a job. The difference is the expected capitalized value of hiring costs (note that the inverse of *QR* equals the average duration of an open vacancy).

In line with this simple theoretical model, the CGE model defines the price faced by the production and trade sectors for the variable labour input by the sum of the wage rate, incl. employer paid taxes and social security contributions, and the search costs (*CSEARCH*). The latter are defined per domestic region and skill type:

*CSEARCH(reg,slab)*
*= (r+sep(reg,slab))*avac(reg,slab)*PA_0(reg,"good17")/QR(reg,slab)*

*Sep(reg,slab)* is the exogenous job separation rate for skill type *slab* in region *reg*. It is assumed that each vacancy requires an input *avac(reg,slab)* of market services, the unit cost of which is given by *PA_0(reg,”good17”)*.

### *Wage bargaining*

The regional wage rate per skill type is set by bargaining between employers and employees:

*PP_lab(reg,slab)*
*= (1-kappa(reg,slab))*reprate(reg,slab)*PW(reg,slab)*
*+ kappa(reg,slab)*scaleB(reg,slab)*AVMP_lab(reg,slab)*

*Kappa* is the bargaining power of the employees. *reprate*PW* is the value of the outside option to the employees. *PW* is the regional gross wage rate, while *reprate* is the share of the gross wage that is covered by the unemployment benefits in the region. *AVMP_lab* is the value of the marginal product of labour averaged over the different sectors in the region.

The bargained wage shares the rent of a filled job, namely the difference between the average value of the marginal product of labour and the outside option to the employee. From the job creation condition it can be seen that if search costs approach zero, the wage rate approaches the marginal product of labour, and from the rent sharing equation it follows that the wage will then approach the outside option.

### *Conditions on labour market flows*

The labour market model is closed by imposing a number of conditions on labour market flows. The first set determines the number of vacancies per domestic region and skill type.

*NV(reg,slab)*
*= (XP_varlab(reg,slab)-COMM("EU",reg,slab)-COMM("ROW",reg,slab)*
*-(1-sep(reg,slab))*(xp_varlab_d(reg,slab)-comm_d("EU",reg,slab)-*
*comm_d("ROW",reg,slab)))/QR(reg,slab)*

*XP_varlab* and *xp_varlab_d* denote the total variable demand for labour inputs, in the current period and the previous period respectively. From this the exogenous commuting flows from the EU or the ROW to *reg* are subtracted (denoted by *COMM* for the current period and *comm_d* for the previous period)

The second set of conditions determines the commuting flows *COMM* from between the domestic regions *reg* and *rega*, per skill type *slab*. It corresponds with the market equilibrium conditions for the labour market.

*COMM(reg,rega,slab)*
*= (X_totlab(rega,slab)-COMM("EU",rega,slab)-COMM("ROW",rega,slab))*
**(comm_d(reg,rega,slab)*(1-sep(rega,slab))+NM(reg,rega,slab))*
*/sum(regb$DOM(regb,rega),comm_d(regb,rega,slab)*(1-*
*sep(rega,slab))+NM(regb,rega,slab))*

*X_totlab* is total labour demand. From this the exogenous commuting flows from the EU or the ROW to *rega* are subtracted. *Comm_d* refers to the commuting flows in the previous period. In the denominator the combined set *DOM(regb,rega)* is used to sum only over the domestic pairs of regions.

The wages in the domestic regions *reg* are determined as follows:

*PW(reg,slab)*
*= SUM(rega,PP_lab(rega,slab)*COMM(reg,rega,slab))*
*/SUM(rega,COMM(reg,rega,slab))*

## Domestic trade and relations with the foreign sector

### *Domestic and international trade*

The formulation of the international trade part of the model is based on the theory for a small open economy. Each Belgian region is a price taker on its import and export markets.

Demand in each Belgian region is a composite of domestically produced commodities, imports from the EU countries and imports from the rest of the world (Figure 6). The domestically produced commodities are a CES-composite of commodities from the region itself and from the other Belgian regions.

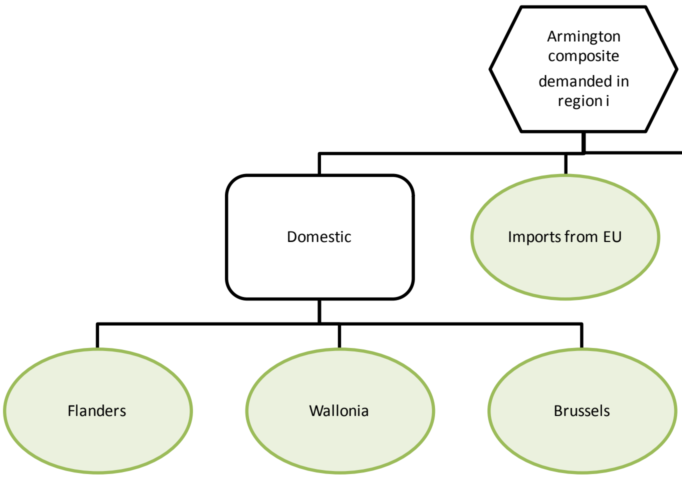



Figure 6: The trade structure in LIMOBEL (by domestic region)

The upper nest in Figure 6 represents international trade. At this level the region chooses to buy domestically produced or imported goods (from the EU or the ROW). This part of the model is based on the Armington assumption of heterogeneity between the commodities produced domestically and abroad (Armington, 1969). Indeed, assuming homogeneity of domestic and imported commodities would lead to a tendency towards specialization when coupled to the small country assumption, which is not observed in reality, and would give rise to unrealistic trade elasticities. We therefore adopt the Armington formulation which allows one to keep aggregative commodity categories across countries but specifies product differentiation by country of origin into the structure of demand. Commodities produced abroad cannot be perfectly substituted with the domestically produced ones. The substitution possibilities between domestic and foreign commodities are described by the elasticity of substitution of the CES production function. If it is high, the domestic and imported commodities are close substitutes.

In the second nest, representing domestic trade, the region allocates the consumption of domestic commodities over the three Belgian regions. Heterogeneity is assumed between the commodities produced in the three regions. The substitution possibilities depend on the elasticity of substitution of the CES production function.

The prices of the commodities from the different regions of origin are given by the output prices of the trade sectors and are a weighted average of the price of the commodities themselves and the costs of the freight transport services.

On the export side, remaining faithful to the small country assumption would entail that export demand by the rest of the world is infinitely elastic. But this is inconsistent with the assumption that products are differentiated by country of origin and imperfect substitutes for one another. We therefore use a constant elasticity demand function to determine the export demand for the commodities produced in the Belgian regions.

*XT_0(freg,breg,good)*
*=bxt_0(freg,breg,good)*
**(p_abr(freg,good)*ber/PT_0(freg,breg,good))**sigma_abr(freg,good)*

In this expression *XT_0* is the export demand in foreign region *freg* for commodity good produced in domestic region *breg*. *bxt_0* is a constant. *p_abr* is the exogenously given world price of the commodity in foreign currency which is transformed into domestic currency using the exchange rate *ber*. *PT_0* stands for the export price of the commodity incl. transport costs. *sigma_abr* is the negative of the elasticity of export demand in the foreign region.

The small country assumption still holds in the sense that a change in the export price does not affect the world price of the commodity, nor the total world demand for the commodity. However, it does affect the region's market share.

### *Transport by foreign transport users in Belgium*

Both in the case of passenger and freight transport, the model should take into account transport by foreign transport users in Belgium.

The input of freight transport used by the trade sectors for domestic and international trade is a composite of domestically produced and imported services. Freight transport by foreign transport users related to domestic production, import and export is therefore taken into account via the modelling of the trade relations. Transit transport requires a different approach since it is unconnected to economic activity in Belgium. It is determined by means of a demand function, where the demand for transit transport through Belgium depends on the level of international trade and the relative transport costs of transport through Belgium and other routes.

At this stage the model does not yet include demand functions for passenger transport by foreigners in Belgium. It could be included in a simple way by using an approach similar to the one used for freight transit transport.

### *The balance of payments*

The balance of payments at the national level is given by all international incoming and outgoing payments. The model allows for a free variation in the balance of payments, while the exchange rate is held fixed. This hypothesis is equivalent to the small open economy assumption. The surplus or deficit on the balance of payments is derived as follows:

> *Surplus on the balance of payments*
> *= value of exports – value of imports – net capital transfers + net foreign labour income + net foreign household transfers + net foreign government transfers + transport taxes paid by foreign transport users in Belgium – transport taxes paid by Belgian transport users abroad.*

The surplus/deficit on the balance of payments reflects the net lending/borrowing of the economy

## Savings and investment

Total domestic savings equal the savings by the domestic households, the governments and the depreciation costs of the domestic production sectors.

Total investments in the Belgian economy equal the sum of domestic savings, the net savings received from the EU and the ROW from which the changes in stocks are subtracted. The total investment budget is allocated to the purchase of investment goods by the three Belgian regions. The investment demand per region and per commodity is determined by maximizing a Cobb-Douglas utility function subject to a budget constraint. The price of the composite investment good is calculated in accordance with this formulation and is a weighted average of the prices incl. transport costs of the different investment goods faced by the three domestic regions.

The nominal rate of return to capital (at the regional or the national level) is calculated as the average return to capital in all sectors of the region or the country.

### Market clearing conditions

Market clearing conditions have to be satisfied for all commodities, labour (per skill type), and capital. For the market equilibrium conditions for the labour market we refer to the discussion above.

For each commodity and each region the following condition needs to be satisfied: the total quantity in the region plus the imported quantity from the other Belgian regions and the international imports should equal the total demand in the region plus the total quantity exported to the other Belgian regions plus the international exports. The total demand in a region is given by the sum of the demand by the households, the firms, the trade sectors, the governments plus investment demand and the change in stocks.

The market equilibrium conditions for capital are formulated by sector. In any given year the total capital input per sector should equal an exogenous level of capital supply per sector.

## MODEL DATA AND CALIBRATION

### Regional Social Accounting Matrices

The Supply and Use tables (SUT), describing in detail the composition of supply and demand of the regional economies, form the core of the Social Accounting Matrix of the model. Due to the lack of data which would be needed to construct regional SUT bottom-up, we have decided to derive the SUT using top-down methods. This section describes the procedure that was followed, its assumptions, and the regional data which have been used (see also Avonds, 2008).

Given data for production, gross value added (VA) and gross wages, plus data on regional household disposable income and regional population, the Use table can be disaggregated. Where possible, the data have been constructed, first using the maximum disaggregation level of goods and sectors available (129 SUT categories). Summation to our 25 sectors and 27 goods has been done only at the end of the calculations to use the maximum amount of information available.

In order to reconstruct the Input–output relations at the regional level, total intermediate consumption is calculated using data on gross production and value added. By sector this total is split into different intermediate goods using a *same product mix* assumption: the composition of regional intermediate demand is assumed to consist of the same proportions of goods as in the national table. The components of value added are regionalized using wages and production. Since wages are given by the data, only depreciation, taxes and subsidies and gross operating surplus need to be reconstructed. The former three categories have been partitioned using regional VA as a percentage of national VA as key. Gross operating surplus is then calculated as a residual category.

Calculation of investment by product is somewhat more involved. Investment by *sector* was available to us at the lowest level of disaggregation (SUT). Also available was a matrix breaking down *national* sectoral investment by sector into different products. This matrix has been used to calculate regional investment by *product* at the lowest level of disaggregation, and has only then been aggregated into coarser product categories. Exports have been partitioned using regional production by good as a key. Production by good is calculated by assuming that regional production by sector, available as data, can be split up using the same market share as in the national supply table. Total regional household consumption is taken from the regional accounts, but we used figures obtained from the household budget survey to partition totals between different commodities.

The database has furthermore benefited from access to detailed figures on the amount of indirect taxation included in each distinct cell of the use table.

### Interregional trade

For any regional CGE model, data on interregional trade flows are usually hard to come by. Surveys on trade within countries are scarce, and Belgium is certainly no exception to that rule. For goods trade, however, we do dispose of data on freight transport. Our trade flows are derived from the TRANSTOOLS database, and are balanced using the entropy minimization program described in Canning and Wang (2005). Survey information on trade in services is at present nonexistent. One quick way of proceeding, is to assume that trade in services would follow the same pattern as, for example, trade in consumer goods. An alternative may be to use the few estimated gravity equations for services that can be found in the literature. Either option does not, however, address a peculiar Belgian problem: that of the language barrier between regions, which we expect to be particular important for services trade.

Estimates for monetary and time costs of freight per tonne, which serve as an input for the trade production function, are taken from the extensive PLANET database (Hertveldt, et al., 2009). Based on the TRANSTOOLS data, total freight costs by NSTR good could be calculated.

### Commuting and regional labour markets

The number of commuters by skill type is based on the Labour Force Survey. The average number of trips per commuter and per zone pair are taken from the 2001 socio-economic survey, while the time and monetary costs per trip are taken from Hertveldt et al. (2009). Regional vacancies are calculated so as to mimic regional unemployment/vacancy rates published by the employment ministry.

### Household Income and transport

The different types of income, labour and capital income, transfers and taxes, are all taken from the regional accounts. The partitioning by household group is based on the data from the Household Budget Survey.

The number of school trips per household and zone-pair are derived from the 2001 socio-economic survey, while average costs are found in Hertveldt et al. (2009).

Although we do have information on the *total* number of leisure trips form the PLANET database, the *distribution* by zone pair has to be deduced using outside data. We use the results of De Vlieger et al. (2010), who deduce the O-D matrices for leisure trips on the basis of counts on the infrastructure, after subtracting known commuting and schooling trips.

### Calibration and elasticities

Elasticities of substitution from the top nests in firm production function are taken from the HERMES model (Bossier et al., 2004). Mark-ups are taken from Christopoulou and Vermeulen (2008) while the number of firms – needed to deduce fixed costs – are taken from the firm data of Bureau van Dijck.

Elasticities for the household production function are estimated based on the household budget survey.

For the trade and household transport production function parameters are chosen such as to yield the same cost elasticities as in the PLANET model (Desmet et al., 2008; Hertveldt et al., 2009).

## CONCLUDING REMARKS

The paper describes the static set-up of a regional computable general equilibrium model for Belgium and its three regions. The CGE approach allows to model the two-way interactions between transport and the economy in general. On the one hand, it models endogenously the implications of economic developments on transport use. Given the focus on transport issues, passenger and freight transport are represented in a more detailed way than in similar models. Transport generation and the interregional trip distribution are determined endogenously, both for passenger and freight transport. The freight flows between the three regions are linked to the trade flows, while the number and distribution of commuting flows follow from the labour market equilibrium. On the other hand the model can be used to determine the indirect impacts of changes in the transport sector on the economic system and the location of activities in the three Belgian regions, taking into account agglomeration effects. This way, one can calculate the full welfare impacts of policy changes, taking into account the impacts on all economic agents and not only on the transport sector. By incorporating different household groups, the equity impacts of policies can also be analysed.

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