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DISCUSSION PAPER 21

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GREEN TAX SHIFT IN A FEDERAL STATE: A REGIONAL CGE ANALYSIS FOR BELGIUM

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Abstract: This paper develops a regional dynamic computable general equilibrium model for analyzing an energy tax reform. In particular, we increase excises on oil in Belgium. Budget neutrality is obtained either by redistributing the additional tax revenues lump sum or by reducing employers. social security contributions. We analyse both federal and regional tax reforms. Significant impact variation of a federal tax reform is found across regions. Both the federal and regional scenario with lower labour taxes suggest that carbon emissions can be reduced without lowering the country's GDP. However, not all regions gain in terms of production and employment. When the largest region implements a green tax shift unilaterally, gains or losses are exacerbated. In addition, we look into the vertical and horizontal government interactions in the Belgian federation where regions are interlinked via common labour and commodity markets and via public finance mechanisms.

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1 Introduction

Climate change policies and environmental taxation have aroused interest already in the early nineties. A substantial amount of work has been done to study 'green tax shifts' and the potential for a 'double dividend'. We identify green tax shifts as a change in the tax system that increases the tax burden on sectors or products that somehow impose a burden on the environment (e.g. activities that are linked to pollution or resource extraction) and decrease the tax rate on another source. One speaks of a double dividend when this kind of measure induces a gain for both the economy and the environment. Recent country recommendations of the European Commission show that environmental taxation is still high on the political agenda[1]. Due to the lack of stringent international agreements on climate change mitigation, policymakers increasingly look at instruments available to lower levels of government to reduce carbon emissions. However, Wolkinger et al. (2012) claim that the lack of quantitative research on the economic effects of sub-national climate change policies is one of the reasons for the ineffective persuit of emission reduction strategies. The contribution of this paper is to shed some light on the effects of regional environmental policy in Belgium. In particular, we study economy-wide effects of increased energy taxes on both the federal and the regional level.

The popular debate in Belgium often starts from the observation that environmental tax revenue is relatively low, whereas taxes on labour are among the highest in Europe. Figure 1 illustrates this. Total environmental tax revenue as a percentage of GDP, displayed on the horizontal axis, includes transport, energy, resource and pollution taxes. The extent of labour taxation, on the vertical axis, is represented by the ratio of taxes and social security contributions on employed labour income to total compensation of employees (data for the year 2005, which will be the base year in our analysis). The figure clearly shows the high extent of labour taxation and a fairly low importance of environmental taxes in Belgium, compared to other European countries. Government competition (Markusen, Morey, and Olewiler 1995) or political economy arguments (Aidt 1998) provide reasons why environmental taxes may be non-optimal in a realistic setting. Figure 1 may provide an important observation, because the potential for a double dividend hinges on the pre-existing distortions and the efficiency of the initial tax system. This makes Belgium a particularly interesting case to study.

[1]European Commission (30 May 2012), *Council Recommendation on Belgium's 2012 national reform programme and delivering a Council opinion on Belgium's stability programme for 2012-2015* (http://ec.europa.eu/europe2020/pdf/nd/csr2012_belgium_en.pdf)

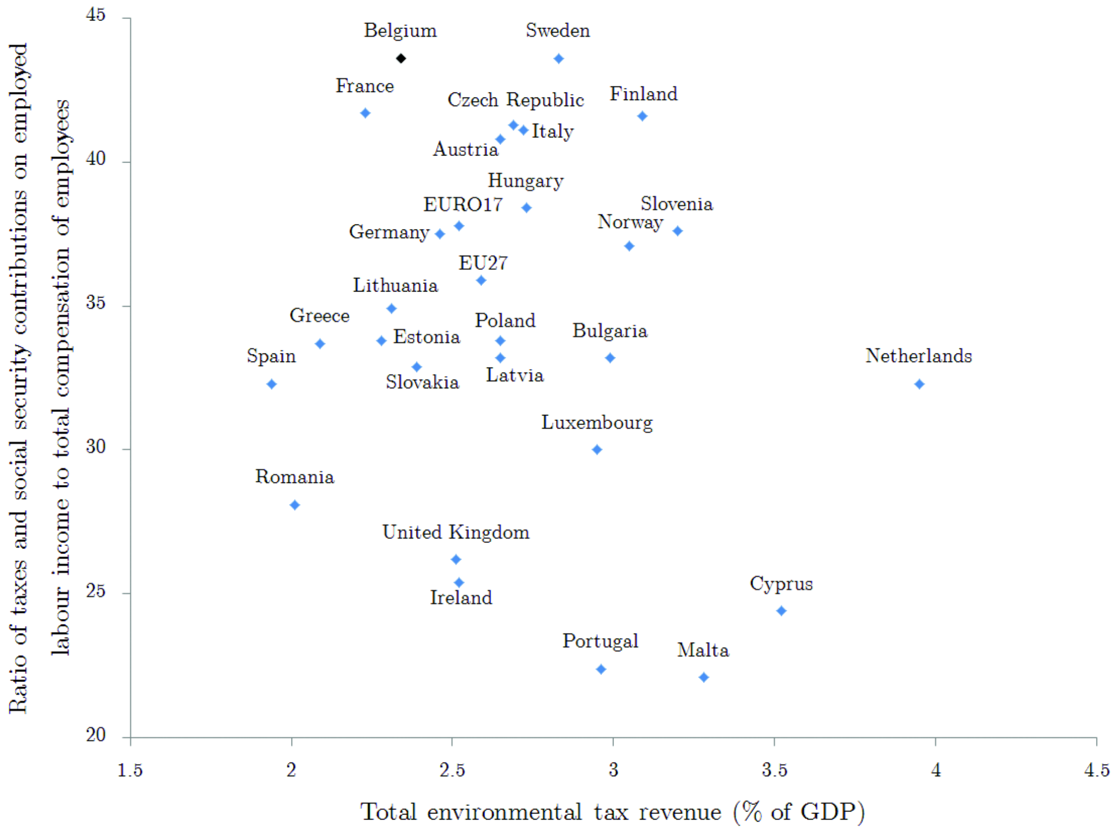

Figure 1: Relatively high labour and low environmental taxation in Belgium (Eurostat, 2005).

The theoretical foundations of environmental taxes go back to Pigou (1952), who observes that externalities can drive a wedge between marginal social net product and marginal private net product. The most obvious way to address this divergence, he claimed, was a tax (or a subsidy in case of a positive externality). The optimality of Pigovian taxes, equal to marginal environmental damages, is well-established in **first-best**, partial equilibrium analysis. In general equilibrium, the effects of a green tax depend on how the revenue it raises is used. This gives rise to the notion of a double dividend. Goulder (1995) makes a distinction between a weak and a strong form of double dividend. A 'weak double dividend' points to the idea that a budget neutral environmental tax reform can enhance tax efficiency by using the environmental tax revenue to lower other distortionary taxes compared to redistributing the additional tax revenue lump sum. A strong double dividend' is found if a shift to environmental taxes from other taxes improves not only environmental conditions, but also non-environmental welfare through enhanced efficiency of the tax system. A weak double dividend is widely supported by theoretical and empirical work. The potential for a strong double dividend and the conditions in which it may arise is surrounded with more debate than its weak form.

In a general equilibrium framework with distortionary taxes (**second-best**), the optimality of

Pigovian taxes does not always hold. Bovenberg and De Mooij (1994) argue that the optimal environmental tax should lie below the Pigovian level when labour taxes distort labour supply decisions. Environmental levies lower the after-tax wage, thereby inducing a lower labour supply, and exacerbate the labour market distortion. In addition, taxing the consumption of a polluting good distorts the composition of the consumption basket. Parry (1995) and Bovenberg and Goulder (1996) present similar theoretical arguments and provide an estimate of the optimal environmental taxes that is lower than the optimal Pigovian tax. Bovenberg (1999) develops a simple general equilibrium model to discuss the link between welfare effects and the changes in unemployment. In addition, Bovenberg uses the theoretical model to illustrate possibilities for a strong double dividend in cases where the initial tax system is inefficient. His analysis shows that the incidence of environmental taxation and the initial tax system are crucial factors for the outcome. This is also the reason why a general equilibrium framework is well-suited for investigating double dividend claims. Highly relevant for this paper is the case where the initial situation is marked by inefficient factor taxation: a high marginal excess burden with respect to labour taxation could provide the scope for a strong double dividend. Proost and Van Regemorter (1995) show that the weak double dividend hypothesis may no longer hold when taking distributional concerns into account. For an inequality averse society, this may be the case when lump sum transfers are directed towards lower income groups. Using a dynamic general equilibrium model with heterogeneous consumers, fixed labour supply and both fixed and flexible wage regimes, they argue that potential efficiency gains have to be traded off against equity considerations.

In a **third best** situation, when there are non-optimal distortionary taxes, few generalizations can be made an a theoretical basis. Numerical applications provide a useful tool for policy analyses in these realistic settings. **Computable general equilibrium** (CGE) models are well-suited for the assessment of the double dividend. The theoretical framework of general equilibrium based on the work of Léon Walras (1952), operationalised since the work of Scarf (1973), has led to policy-oriented CGE models already in the Seventies (e.g. Shoven and Whalley (1973)). We refer to Böhringer and Löschel (2006) for an overview of the use of CGE models for the environmental, energy and economic policy appraisal and to Bosello et al. (2001) for a review of empirical findings on the double dividend. Recently, CGE models at the **regional** level are increasingly used in regional policy analysis (Partridge and Rickman (2010); for an earlier overview see Partridge and Rickman (1998)). Regional models allow a study of the impact of federal tax reforms on regions within a federation. In addition, they enable us to look into the effects of regional policy measures, including the effects on neighbouring jurisdictions and on higher level governments. Andre et al. (2005) provide an example of a CGE analysis of an environmental tax reform in the region of Andalucía in Spain. Their model with fixed production technology (nested; combination of Leontief and constant elasticity of substitution) does not allow factor substitution away from energy as an input in the production process. Energy is not further detailed by source or fuel type. Pollution intensities of 24 sectors are fixed but heterogeneous across sectors, so the environmental tax comes down to an ad valorem tax on output, differing by sector. Four scenarios are discussed, depending on which pollutant is taxed (CO_2 or SO_2) and on the revenue recycling option (lower payroll tax or income tax). A strong double dividend (reduction in emissions and increase in regional GDP) is found for taxes on CO_2 when tax revenue is recycled through a reduction in payroll taxes.

Proost and Van Regemorter (1992) discuss carbon taxes as instrument to reach national emission reduction goals that are set by an international agreement. Since few general conclusions can be made in a situation with pre-existing non-optimal distortionary taxes ('third best'), they present a general equilibrium application of excises on CO_2 generating fuels in **Belgium**. A two-period dynamic perfect foresight model is used to simulate an increase in excises (differing per fuel type) that doubles energy prices, of which the revenue is redistributed lump sum to the representative consumer. Labour supply is exogenous, whereas the substitution between labour and capital in the production process is modelled endogenously using a constant elasticity of substitution specification. Results suggest that a relatively small welfare loss has to be occurred in order to reduce CO_2 emissions by approximately 30%. A scenario with rigid wages, however, shows more substantial welfare losses. Changes in sectoral composition (a shift away from energy-intensive industries), a real wage decrease to remain competitive, an increase in energy efficiency and changes in the energy mix (an increase in the market share and sales in absolute terms of gas) are some of the important effects on the Belgian economy.

This paper develops a dynamic regional CGE model to study federal and regional energy tax reforms reforms in Belgium. We look into the effects of increased energy taxes on firms and households in the federation as a whole or in the largest region. Numerical simulations illustrate how the impact varies with alternative revenue recycling instruments and differences in sectoral composition across regions. In particular, we highlight the importance of shared labour and commodity markets and regional linkages via public finance mechanisms. The next section describes the regional computable general equilibrium model. Section 3 discusses the main results. We summarize and conclude in section 4.

2 The CGE model: REGGA-E3

The analyses will be done with the regional recursive-dynamic CGE model REGGA-E3 (**Reg**ional **G**eneral equilibrium **A**nalysis for **E**conomy, **E**nergy and **E**nvironment interactions), in which the three regions in Belgium are represented: Brussels, Flanders and Wallonia. This model is largely based on the GEM-E3 model[2]. The GEM-E3 model is particularly well-suited to deal with problems that include interactions between energy, environment and economy. For a recent example of an application of GEM-E3 we refer to a publication by Saveyn et al. (2011). They analyse the impact of several Greenhouse gas emissions reduction schemes with a version of the GEM-E3 model covering the whole world and including auctioning of emission permits. This section provides details on the derivation of the model and points out the specific regional aspects.

2.1 Consumption

In each region, a representative household maximises intertemporal utility U (Stone-Geary utility function) under an intertemporal budget constraint:

$$\underset{C_t, L_t}{Max}\ U = \sum_t (1 + stp)^{-t} \left(\beta_C \ln(C_t - \gamma_C) + \beta_L \ln(L_t - \gamma_L)\right) \tag{1}$$

$$s.t. \sum_t (1+r)^{-t} p_{C,t} C_t = \sum_t (1+r)^{-t} (y_{TR,t} + p_{L,t}\overline{L_t} - p_{L,t} L_t) \tag{2}$$

We denote the subsistence levels of consumption C_t and leisure L_t with γ_C and γ_L respectively. Parameters β_C and β_L are the shares of consumption and leisure in the disposable income. Subscript t indicates time, stp is the household's subjective time preference and r is the interest rate. Non-labour income, e.g. received transfers from the government, is represented by y_{TR}. The total time endowment in period t is denoted by $\overline{L_t}$. Household preferences are modeled with a nested structure (see schematic presentation in figure 2). We assume preferences are identical across regions. We model 13 consumption categories, 2 of which are durables (see table 6 in appendix A).

On the first level, the household chooses the amount of consumption goods C_t (with price $p_{C,t}$) and leisure time L_t (with price $p_{L,t}$). The latter choice determines the labour supply (subtracting leisure time L_t from total time endowment $\overline{L_t}$) and, consequently, the disposable income. What remains after consumption spending are savings, which are assumed to be positive. Behaviour is based on myopic expectations: the household decides on consumption and leisure using only the prices in the current period. Furthermore, no transportation cost for goods is included, so there is a common consumption goods market and commodity prices will be equal across regions. Households are assumed to spend their income within their region of residence, so we neglect cross-border shopping.

[2] An extensive manual can be found on http://www.ecmodels.eu/index_files/Manual_of_GEM-E3.pdf or http://ipts.jrc.ec.europa.eu/activities/energy-and-transport/gem-e3/.

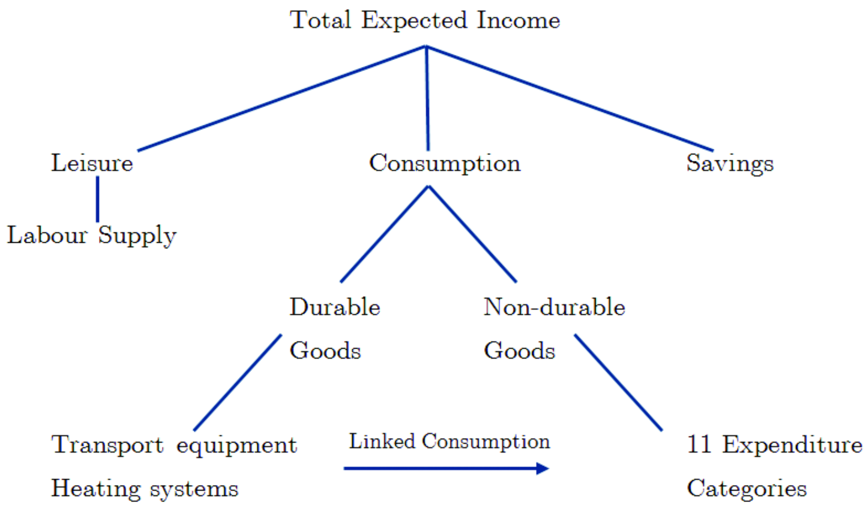

Figure 2: Nested consumption structure.

From the consumer's problem given by expressions (1) and (2), we can derive (appendix C) the demand functions for consumption C_t and leisure L_t. Expressing the first order conditions for the current period ($t = 0$) and substituting the value of the Langrange multiplier, we obtain consumption demand C_t and leisure demand L_t in a Linear Expenditure System (LES):

$$C_t = \gamma_C + \frac{stp}{rr}\frac{\beta_C}{p_{C,t}}(y_{DISP,t} + p_{L,t}L_t - \underbrace{(p_{C,t}\gamma_C + p_{L,t}\gamma_L)}_{obliged\ consumption}) \tag{3}$$

$$L_t = \gamma_L + \frac{stp}{rr}\frac{\beta_L}{p_{L,t}}(y_{DISP,t} + p_{L,t}L_t - \underbrace{(p_{C,t}\gamma_C + p_{L,t}\gamma_L)}_{obliged\ consumption}), \tag{4}$$

where we have used $\beta_C + \beta_L = 1$. Labour supply, is then easily derived as $\overline{L_t} - L_t$. We denote the real interest rate with rr. The disposable income is labelled $y_{DISP,t}$ and includes labour income and received transfers. As noted by Partridge and Rickman (1998), the LES structure has the advantage of nonhomotheticity, such that additional income does not necessarily increase consumption of all commodities proportionately and budget shares of goods can vary with the level of income.

On the second level of the nested consumption structure, the representative household allocates total consumption C_t over the consumption of non-durable goods, $C_{ND,t}$, and a stock of durable goods, $S_{DG,t}$. Durable goods are modelled as a stock that depreciates at a yearly rate d_H. Remark that the use of a durable good is linked to the consumption of a non-durable good, $C_{LND,t}$. More specifically, the use of heating systems (category 6 in table 6) involves the consumption of fuels and power (category 4). The use of transport equipment (category 8) is linked to category 9, operation of transport equipment. Therefore, the households takes both the cost to acquire the durable and the cost to use it into account when deciding on the level of the stock of durables (the relative price of the linked non-durables, $p_{LND,t}$, is included in the cost of durables $p_{DG,t}$).

2.2 Production

Firms' production technology is modelled by a nested constant elasticity of substitution (CES) specification, of which the structure is shown in figure 3 (with elasticities of substitution σ). The nesting of the production structure allows for more complex substitution patterns in the production process. Labour (labelled $L_{D,t}$ for labour demand in time t) and capital K_t are the primary inputs. The Belgian regions are strongly connected via the labour market. On a daily basis, the capital region of Brussels, with over one million inhabitants, attracts over 350'000 commuters from neighbouring regions Flanders and Wallonia[3]. We assume perfect labour mobility (between regions and sectors), so there is a common labour market within the country. Since migration is absent from the model, this labour mobility boils down to interregional commuting flows. Total capital stock is fixed within one period of time (five years). In addition, the capital stock is assumed to be fixed per sector and per region within this period. Firms attain the desired stock of capital in next periods by investing. Therefore the model is dynamic through accumulation of capital stock over time. This section first clarifies firm behaviour and derives factor demands. Remark that we do not include technological innovations and (advances in) renewable energy production. We acknowledge these are important ingredients for an economy with a lower carbon intensity, but they are beyond the scope of our analysis.

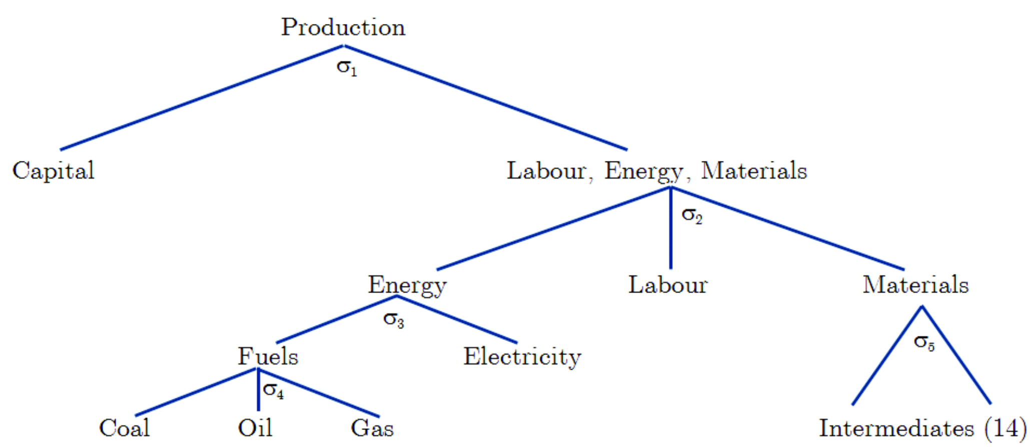

Figure 3: Nested CES production structure.

The **first level** of the profit (π_t) maximisation problem entails substitution between the desired stock of capital K_t and an aggregate of labour, energy and materials (the latter is an aggregate of intermediate inputs) LEM_t with a substitution elasticity σ_1, and can be stated as[4]:

[3] Year average 2008-2009. Source: Vlaamse Arbeidsrekening (www.steunpuntwse.be).

[4] Note that the optimization is done by each industry branch in each region. For notational simplicity we do not include subscripts to indicate this.

$$\underset{K_t,LEM_t}{Max}\ \pi_t = p_{D,t}X_{D,t} - p_{K,t}K_t - p_{LEM,t}LEM_t \quad (5)$$

$$s.t.\ X_{D,t} = \left[\delta_K^{\frac{1}{\sigma_1}} K_t^{\frac{\sigma_1-1}{\sigma_1}} + \delta_{LEM}^{\frac{1}{\sigma_1}} LEM_t^{\frac{\sigma_1-1}{\sigma_1}}\right]^{\frac{\sigma_1}{\sigma_1-1}} \quad (6)$$

where total domestic production $X_{D,t}$ in time t is modelled by a CES production function with constant returns to scale. We assume perfect competition, so profits are zero. Therefore, firms have no market power and take production price $p_{D,t}$ (which reflects unit production cost; see appendix B), rents on capital $p_{K,t}$ and the price of the labour-energy-materials aggregate $p_{LEM,t}$ as given. In the short run, total capital stock is fixed, leading to decreasing returns to scale. Return on capital is then paid out to the shareholders (the firm itself and households). The scale parameters δ_K and δ_{LEM} are fixed in the calibration. We derive (appendix D) optimal factor demands by solving the profit maximisation problem in equations (5) and (6). The optimal capital stock K_t and the demand for the labour-energy-materials aggregate LEM_t is given by

$$K_t = \left(\frac{p_{D,t}}{p_{K,t}}\right)^{\sigma_1} X_{D,t}\delta_K \quad (7)$$

$$LEM_t = \left(\frac{p_{D,t}}{p_{LEM,t}}\right)^{\sigma_1} X_{D,t}\delta_{LEM} \quad (8)$$

Equation (7) expresses the desired stock of capital in period t. However, the actual level of capital stock of a firm is determined by its investment decision (see appendix E) in period $t-1$, based on myopic expectations. Since firms' expectations on relative prices and on the level of production is not necessarily correct, the actual level of capital stock can differ from the desired level K_t. For the composition of the LEM-bundle, we solve a cost minimisation problem on the **second level** of the nested production structure. This will give us the demand for production factors labour $L_{D,t}$, energy E_t and materials M_t. A similar procedure applies for lower levels of the production structure.

Industry branches are aggregated into 18 sectors, as illustrated in table 1 below[5]. Furthermore, table 1 displays the relative importance of these industry branches in the different regions (as captured by the input-output tables). Belgium's regions provide a significant degree of heterogeneity in sectoral composition. For instance, Brussels is more service-oriented (branches 16-17-18). Flanders has a relatively more important share of consumer goods industries (branches 10-11-12). In Wallonia, energy-intensive industries (branches 6-7-8) play a more important role. In addition, the public sector (branch 18) represents a relatively large share of regional production in Wallonia. This regional differentiation is taken into account in our model.

[5] The explanation of the CPA (statistical Classification of Products by Activity) codes in brackets are listed in appendix F.

	Industry branches (CPA aggregation)	*Belgium*	*Brussels*	*Flanders*	*Wallonia*
1	Agriculture (01,02,05)	1.53	0.64	1.72	1.74
2	Coal (10)	0.07	0.09	0.04	0.11
3	Crude oil and refined oil products (23)	3.26	6.90	2.68	1.97
4	Natural gas (11)	0.43	0.24	0.62	0.02
5	Electric Power (12,40)	1.88	2.97	1.51	2.06
6	Ferrous and non-ferrous ore and metals (13,27,28)	4.69	1.28	4.90	**6.87**
7	Chemical products (24)	7.51	4.08	8.11	**8.60**
8	Other energy intensive industries (14,21,26)	3.15	1.54	2.95	**5.03**
9	Electrical goods (29,30,31,32,33)	6.23	3.82	6.99	6.01
10	Transport equipment (34,35)	5.91	4.65	**7.48**	2.40
11	Other equipment goods (20,22,25,36,37)	4.38	2.76	**5.03**	3.80
12	Consumer goods industries (15,16,17,18,19)	7.42	4.37	**8.37**	7.17
13	Building and construction (45)	5.52	4.14	5.77	5.91
14	Land Transport (60)	1.94	1.63	1.94	2.20
15	Other Transport (61,62)	0.87	0.68	1.08	0.41
16	Credit and insurance (65,66,67)	4.70	**11.12**	3.20	3.79
17	Other market services (50,51,52,55,63,64,70,71,72,73,74)	29.45	**36.52**	28.06	27.68
18	Non-market services (41,75,80,85,90,91,92,93,95)	11.05	**12.58**	9.52	**14.24**

Table 1: Production by branch in % of total regional production (Input-Output tables, 2005).

2.3 Federal and regional governments

It is important to remark that there is no optimising behavior included on the governments' behalf. Government behavior is largely exogenous. Therefore, the tax and subsidy scheme that is incorporated is not assumed to lead to a welfare optimum, but is based on data observed in regional and federal government accounts. Possible explanations for the suboptimality of the initial tax system are competing governments, distributional concerns or pressure of interest groups. Our analysis is one in a third-best situation, where a government can only change its policy using a limited set of instruments.

For both federal and regional governments, we model several tax and transfer instruments. In particular, we include social security contributions by firms and households, direct taxes on firms and households, import duties, value-added taxes on consumption, indirect taxes on production, subsidies to firms, energy taxes on the input of oil in the production process and on the use of durables for households. The finances of regional and federal governments are interlinked via the revenue sharing mechanism. The Special Financing Act, that distributes tax revenues between federal and regional governments, is modelled explicitly. Government expenditures can be categorised in three groups: investments (of branch 18: non-market services), transfers to households and public consumption, which is exogenous and is assumed to grow in volume at a yearly rate of 1%.

2.4 Trade

Since Belgium has a small, open economy, it is important to include import and export. We neglect interregional trade. Total demand Y_t (by industry branch) within the country in period t, consisting of intermediate demand, private consumption, government consumption, investment demand (and stock variation, calibrated per unit of production and fixed), is allocated between domestic products ($Y_{DOM,t}$) and imports (Z_t) according to the Armington (1969) specification (see appendix G). Therefore, domestically produced goods and imports are considered to be imperfect substitutes. In the same fashion, we model exports from a point of view of the rest of the world who imports part of its exogenous world demand $Y_{W,t}$. Imports and export change in response to variations in relative prices.

2.5 Equilibrium conditions

Next, we turn to the discussion of the market equilibrium conditions. The **labour** market equilibrium determines the wage w_t:

$$L_{D,t} = \overline{L_t} - L_t \tag{9}$$

The left-hand side of (9) represents labour demand, given by expression (22). The right-hand side shows labour supply by subtracting leisure time L_t, as given by expression (4), from the total time endowment $\overline{L_t}$. Both sides of equation (9) express a country aggregate, because labour is perfectly mobile within the country. This labour market equilibrium condition therefore reflects the common labour market. The capital rent p_K is defined by the equilibrium on the **capital** market. Expression (10) reflects the capital market equilibrium when we assume that capital is fixed per sector and per region within one period:

$$(1-d)^5 K_{t-1} + \frac{1-(1-d)^5}{d} I_{t-1} = \left(\frac{p_{D,t}}{p_{K,t}}\right)^{\sigma_1} X_{D,t}\delta_K \tag{10}$$

Total supply of capital stock is perfectly inelastic within one period and determined by the capital stock and investments in the previous period, $t-1$. Demand for capital stock in period t consist of the desired capital stock in time t as derived in section 2.2. Commodity prices $p_{DOM,t}$ (a vector of prices by branch) are derived from the **goods** market equilibrium per industry branch:

$$X_{D,t} = Y_{DOM,t} + EXP_t \tag{11}$$

This expression states that domestic production equals domestic consumption plus exports. The trade balance is flexible, so the surplus of the rest of the world can vary and the real interest rate is fixed. Finally, the public sector budget equilibrium fixes government surplus relative to GDP. This is done because our analysis looks at a budget neutral policy reform. From the equilibrium prices w_t, $p_{K,t}$ and $p_{DOM,t}$, all other prices in the model can be derived. The model is implicitly closed by imposing the zero profit condition, complete use of income, the equilibrium on the goods market and the government budget constraint. Appendix H explains the model closure with a stylised example and shows expressions of all prices included in the model.

2.6 Data and calibration

In the calibration, parameter values are fixed such that the model outcome reflects the data in the base year 2005. If a CGE model is to generate trustworthy results, it must rely on consistent data. Mercenier and Yeldan (1999) emphasize that the quality of the data is a crucial aspect for policy analysis in developing countries. The authors' remarks may also apply to regional CGE analyses, because regional data is often harder to find than data on the national level. The regional Social Accounting Matrices (SAM) on which we calibrate the model have been constructed by combining several data sources in a consistent way. Intermediate demand has been constructed by updating (from 2003 to 2005) and aggregating (into 18 industry branches) regional input-output tables. Data on final demand for industry outputs by households, governments and the rest of the world (exports) was provided by the Federal Planning Bureau. This institution also prepared the numbers on consumption of fixed capital, taxes and subsidies by sector. Data on commuting, population, wages and employment are used to derive regional labour input. Regional energy balances are combined with information on tax rates of the International Energy Agency (IEA) to calibrate energy taxes. The energy balances, in combination with the default emission coefficients from IPCC (2006), also serve to calculate the CO_2 emissions of firms. Finally, statistics on transfers between agents are constructed using household and regional and federal government accounts. The regional SAM for Flanders is (partially) shown in table 14 in appendix I.

3 Numerical simulations

We analyse the impact of a green tax shift on the federal and regional level in Belgium. Section 3.1 first decribes the scenarios. What follows is a discussion of the results. Aggregate economic effects are presented in section 3.2. Next, we zoom in on the impact on energy use and carbon emissions in section 3.3 and highlight some interactions in regional public finances in section 3.4.

3.1 Scenarios

The model described in section 2 will be used to simulate an increase in environmental taxes. In Belgium, excises on mineral oil cover more than half of the total environmental tax revenue (Eurostat, 2005). The simulations we present here bring the tax **rate** on mineral oil up to the average rate of the Member States of the European Union[6]. This implies an **increase of oil excises of approximately 8%**. We believe the relatively small scope of the reform can be justified by international tax competition and political economy arguments. Excises are levied both on the consumption and on the production side. For **households**, the tax τ_{en} is levied on the consumption of non-durables that is linked to the use of the stock of durables. Since we do not model substitution possibilities for linked non-durables, we will not replicate households' switching behavior in terms of fuel use for durables. The behavioural reaction of households does include a decreased acquisition of stocks of durables and a lower use of durables. In the case of **firms**, the excise τ_{EN} falls on the use of oil in the production process. We can expect firms to substitute away from oil towards other inputs. Also, higher oil prices can increase production costs and therefore discourage production. Environmental policy instruments in Belgium are mostly at the federal level. At the regional level there is a limited scope for green taxes, mainly consisting of transport, water and waste levies. Therefore, it is useful to remark that the regional energy tax studied in this paper is of hypothetical nature.

Four scenarios are discussed. They have in common an increase in oil excises of 8%. The four scenarios differ in the level of government that implements the reform (federal or regional) and how the additional revenue is recycled (lump sum or via a reduction in labour taxes):

- **Federal** government, **lump sum** revenue recycling: the additional revenue of a country-wide increase in energy taxes is redistributed to the households by means of a lump sum transfer.
- **Federal** government, revenue recycling via **labour tax** reductions: budget neutrality is obtained by recycling the extra revenues through reduced social security contributions on the employer's side ($\tau_{SS,F}$).
- **Regional** Flemish government, **lump sum** revenue recycling: the regional government of Flanders raises the oil excises and redistributes the tax revenue to the Flemish households.
- **Regional** Flemish government, revenue recycling via **labour tax** reductions: higher energy taxes in Flanders, but social security contributions on the employer's side are reduced locally[7].

[6] Data on tax rates from Internation Energy Agency (2005) for the EU, excluding Cyprus, Luxemburg and Malta.
[7] Note that social security is a federal competence in Belgium.

In all scenarios, the trade balance on the country level equals the level in the baseline and the real interest rate is flexible. Budget neutrality for the government that implements the reform is achieved via the instruments mentioned above. The surplus of the other governments relative to nominal GDP at factor prices is fixed to the level of the baseline by lump sum taxes or transfers.

3.2 Aggregate economic effects

Table 2 presents the aggregate economic effects of all four scenarios. The results are expressed as percentage differences (in quantities) from the baseline in 2050. Although the model is dynamic, we present only the numbers for 2050 because the results appear fairly stable. The **first panel** shows the impact of a federal increase in oil excises when the additional tax revenue is redistributed to the households in a lump sum fashion. These numbers reveal several mechanisms included in the model. First, the higher energy taxes appear to be a burden for firms in all regions, as illustrated by the lower production levels (Gross Domestic Production, GDP). However, the impact varies significantly across regions. The region of Wallonia, in which energy intensive sectors play an important role, faces a stronger decrease of regional production than the region of Brussels, which hosts mainly headquarters, banking, insurance and other services that are less affected by energy taxes. Second, the country level employment and (countrywide and regional) investment reduction is slightly lower than the decrease in production, indicating a minor shift from energy towards labour and capital as inputs in the production process. Third, the regional employment changes illustrate the functioning of the common labour market. The overall reductions in production and labour demand lower the real wage rate by 0.03%. However, this wage decrease hides the regional impact variation. If the region of Brussels (*Wallonia*) would operate in isolation, the wage drop would be less strong (*stronger*). With a common labour market, the strongly urbanised area of Brussels benefits from the relatively strong production decrease in Wallonia through depressed costs of hiring labour. As a result, employment increases 0.16% in Brussels, but decreases 0.16% in Wallonia. The perfect mobility of labour enables workers to change employment location at no cost. Fourth, redistributing the additional tax revenue as a lump sum transfers to the households seems to compensate for the wage loss when we look at household consumption on the country level. Note that these additional revenues come from energy tax payments of both firms and households. However, the consumption level of residents of Brussels is lower than the baseline level. This is mainly attributable to the additional lump sum tax levied by the regional government of Brussels to close its budget, which will be discussed in more detail in section 3.4. Fifth, the increased energy taxes raise production costs and drive up the overall price level by 0.08%. Higher costs lead to a loss of competitiveness compared to the rest of the world, which is reflected in reduced quantities of exports. The drop in production and a fixed trade balance lower the total quantity of imported goods.

The **second panel** of table 2 shows the results of the scenario in which the additional revenues of increased energy taxes are recycled by lowering federal labour taxes. A first observation is that the shift from labour to energy taxes does not seem to lower the level of total production in Belgium (a slight increase of 0.0049%). Nevertheless, the burden of increased excises on oil reduces production, employment and investment in the area of Wallonia, where energy intensive industries are more important than in the rest of the country. Second, in response to the higher energy and lower labour costs, firms in Flanders and especially Brussels increase labour demand, which drives up the real wage rate by 0.12%. Consequently, firms in Wallonia reduce the share of labour inputs in the production process. Third, higher income from labour raises disposable incomes and consumption in all regions. Inhabitants of Wallonia benefit from the rise in the number of jobs in Brussels and Flanders, since labour is perfectly mobile. Fourth, the increase in overall price level is lower than in the previous scenario because the labour tax reduction lowers production costs. Therefore, the fall in exports is lower than in the case where additional tax revenue is redistributed to the households.

The results displayed in the **third panel** of table 2 quantify the aggregate economic impacts of a scenario in which Flanders implements a green tax shift unilaterally. In particular, this scenario looks at a regional increase in energy taxes in Flanders when the revenue is recycled as a lump sum transfer to Flemish households. Such a regional tax reform has several distinct effects. First, imposing an additional tax relocates production from Flanders to the neighbouring regions, where regional GDP increases. Overall, however, the level of production drops. Higher labour demand in Brussels and Wallonia keeps real wages stable (increase of 0.0001%), such that employment drops by 0.12% in Flanders. Second, the negative impact on production, employment and investments is more pronounced when Flanders acts alone than in the case where the federal government implements a green tax shift in all regions (as shown in the first panel of figure 2). The Flemish regional policy appears to cause positive spillovers for production in the neighbouring regions. Due to the cost increase for Flemish firms, companies in the other regions are now more competitive on the country wide commodity markets. The negative impact on household consumption in Brussels again relates to regional government budget neutrality, as will be discussed in section 3.4.

On the contrary, when the regional government of Flanders uses the additional revenue to lower labour taxes locally (**fourth panel** of table 2), production in this region increases. Due to the reduced labour costs, Flanders attracts more workers and the real wage rate rises 0.05%. As a result, the level of production in Brussels and Wallonia declines by 0.09% and 0.08% respectively. Note that employment in these regions drops by only 0.03% and 0.06% respectively. This can be explained by the fact that some industries (mainly sector 8: other intensive industries and sector 14: land transport) in Flanders bear a large share of the cost of increased excises on oil due to their input structure. These industries experience a reduction in output. In Brussels and Wallonia, these industries now expand their market shares and production levels and hire more labour.

Federal gov. - Lump sum	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	-0.03	-0.01	-0.02	-0.07
Employment	-0.02	0.16	-0.02	-0.16
Investments	-0.02	0.01	-0.01	-0.06
Household consumption	0.01	-0.02	0.02	0.00
Real wage	-0.03			
Exports	-0.06			
Imports	-0.03			
Price index	0.08			

Federal gov. - Labour tax	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	0.00	0.04	0.01	-0.04
Employment	0.04	0.27	0.02	-0.11
Investments	0.00	0.04	0.01	-0.04
Household consumption	0.04	0.01	0.06	0.03
Real wage	0.12			
Exports	-0.02			
Imports	-0.01			
Price index	0.06			

Flemish gov. - Lump sum	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	-0.02	0.02	-0.04	0.01
Employment	-0.01	0.22	-0.12	0.07
Investments	-0.02	0.02	-0.05	0.03
Household consumption	0.01	-0.05	0.02	0.01
Real wage	0.00			
Exports	-0.04			
Imports	-0.02			
Price index	0.05			

Flemish gov. - Labour tax	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	0.00	-0.09	0.06	-0.08
Employment	0.01	-0.03	0.06	-0.06
Investments	0.00	-0.04	0.02	-0.02
Household consumption	0.02	-0.05	0.04	-0.01
Real wage	0.05			
Exports	-0.01			
Imports	-0.01			
Price index	0.04			

Table 2: Aggregate economic results for the four scenarios: % difference from the baseline in 2050

3.3 Environment and energy

Table 3 highlights some results relating to energy efficiency and carbon emissions. The impact on regional GDP is repeated for the ease of interpretation. A first observation comes from the **production of energy intensive sectors**: metals (6), chemical products (7) and other energy intensive industries (8). These industries may strongly oppose the tax reform under study, claiming that they will be affected most negatively. The country level results confirm that production of the energy intensive sectors decreases more than average in all four scenarios. However, this result does not always carry through on the regional level. In the scenario with a federal energy tax increase and lump sum revenue recycling (first panel of table 3), energy intensive industries in Wallonia appear to be less affected by the reform than other sectors in this region. In this example, consumer goods industries (sector 12) and the sector of land transport (sector 14) seem to be hit harder by the reform. When Flanders implements the environmental tax shift and lowers labour taxes (fourth panel of table 3), the production level of energy intensive sectors even rises, albeit less than regional GDP in this region.

Second, the overall **energy intensity** is reduced in all four scenarios. Since the tax reforms raise oil excises for both households and firms, the energy intensity is measured as the energy use of firms and households relative to GDP. For the federal increase in energy taxes (first and second panel of table 3), the decoupling of energy use and production is strongest in Wallonia. When the Flemish government increases energy taxes and redistributes the revenue to its inhabitants (third panel), energy efficiency is increased in this region. Reverse effects are found in the other regions: energy intensive sectors increase the level of production, leading to a higher energy intensity. Therefore, the energy intensity reduction in Flanders of 0.31% is partially offset by the other regions in the federation, such that energy intensity only drops by 0.16% on the country level.

Finally, we look into changes in the level of **CO_2 emissions**. In all scenarios, carbon emissions are lower than in the baseline. The decrease in emissions is strongest when the federal government coordinates the higher energy taxes in all of the three regions. Furthermore, emissions drop more when the revenue is recycled lump sum compared to scenarios where labour taxes are reduced. This is explained by the negative effect on production in scenarios with lump sum revenue recycling. The carbon emissions in the regional reform scenarios deserve further attention. When the additional revenue is redistributed to the households (panel three), a carbon leakage effect arises: energy intensive firms relocate in Brussels and Wallonia, raising energy intensity and carbon emissions in these regions. This effect does not occur when the Flemish government reduces labour taxes (panel four). In this case, cheaper labour inputs appear to improve the competitive position of energy intensive firms in Flanders. Consequently, energy intensive industries in Brussels and Wallonia lower production levels and emissions of CO_2 decrease. As a result, the green tax shift in Flanders leads to carbon emission reductions in all regions.

The federal reform where the additional energy tax revenue is used to lower labour taxes results in carbon emission reductions while not lowering the country-wide production level. This also holds for the regional reform with lower labour taxes. In this case, the Flemish region increases regional GDP by 0.14% and reduces CO_2 emissions by 0.17%. These results point to the potential for a strong double dividend. However, in both scenarios, production levels in some regions decrease. The results therefore highlight regional impact variation and tax incidence of the reforms studied.

For more detailed results, we refer to appendix K. Tables 17 and 18 show consumption price changes by commodity and the impact on production levels by sector respectively.

Federal gov. - Lump sum	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	-0.03	-0.01	-0.02	-0.07
Production energy intensive sectors	-0.07	-0.51	0.00	-0.06
Overall energy intensity	-0.18	-0.06	-0.16	-0.31
Carbon emissions	-0.23	-0.11	-0.22	-0.33
Federal gov. - Labour tax	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	0.00	0.04	0.01	-0.04
Production energy intensive sectors	-0.04	-0.23	0.01	-0.06
Overall energy intensity	-0.20	-0.03	-0.18	-0.34
Carbon emissions	-0.22	-0.08	-0.21	-0.32
Flemish gov. - Lump sum	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	-0.02	0.02	-0.04	0.01
Production energy intensive sectors	-0.04	0.17	-0.17	0.16
Overall energy intensity	-0.16	0.15	-0.31	0.17
Carbon emissions	-0.17	0.05	-0.33	0.10
Flemish gov. - Labour tax	***Belgium***	***Brussels***	***Flanders***	***Wallonia***
GDP	0.00	-0.09	0.06	-0.08
Production energy intensive sectors	-0.03	-0.54	0.07	-0.02
Overall energy intensity	-0.14	-0.03	-0.25	0.09
Carbon emissions	-0.14	-0.17	-0.17	-0.06

Table 3: Energy and environmental results: % difference from the baseline in 2050

3.4 Regional public finances

In addition to common labour and product markets, regions in the Belgian federation are connected via mechanisms in public finance. Some of these interactions are demonstrated by the results displayed in table 5. Before discussing these results, it is instructive to look into the benchmark. Table 4 shows the relative importance of different aspects of regional budgets in the baseline.

	Federal	***Regional Government***		
Baseline	***Government***	***Brussels***	***Flanders***	***Wallonia***
Transfers from Direct Tax revenue	10604.23	920.16	6717.07	2967.00
Transfers from VAT revenue	9810.77	946.46	5714.61	3149.70
Solidarity Transfers	964.87	43.73	-	921.14
Indirect taxes	-	8725.73	20155.94	8118.92
Subsidies (-)	-	4541.25	7086.75	4045.57

Table 4: Public finances in the baseline in 2050, in million € 2005

The first three lines of table 4 relate to the distribution of federal tax revenue from personal incomes taxes and VAT taxes to the regions, as embodied in the Special Financing Act (2005). We distinguish three parts. First, a (fixed and indexed) amount of the personal income taxes (direct tax) is allocated to regional governments mainly on the basis of the share of personal income tax revenue collected in that region. Second, a (fixed and indexed) sum of the VAT tax revenue is redistributed to the regions largely based on a needs criterion, here approximated by regional population numbers. A smaller part (less than 10%) of the transfer of VAT revenue is allocated in the same way as the transfers from the direct tax revenue. Third, by means of a solidarity mechanism, the federal government hands out a (fixed and indexed per capita) sum according to the deviation from average per capita direct tax income to regions where this per capita direct tax income is lower than the country-wide average. Table 4 illustrates that this third component is relatively small compared to the previous two. Furthermore, the numbers in table 4 emphasize the relative importance of indirect taxes other than VAT and subsidies, the two regional instruments in our model, in Brussels. Note that subsidies are paid mainly to agriculture (sector 1), land transport (14), other transport (water and air, 15) and the sector of non-market services (public sector, 18). The importance of indirect taxes and subsidies in Brussels is driven by the relatively high share of the country's production and jobs in this region compared to the proportion of the population that lives there. In addition, a higher population density in this region leads to a higher demand for public transport investments, which are partially subsidized.

Table 5 illustrates the impact of the four scenarios on public finances. We focus on the first panel: this allows us to illustrate some of the less obvious mechanisms in detail. First, we discuss the impact on **indirect tax revenue** (other than VAT). Due to higher energy taxes, firms shift away from oil as an input in the production process. However, intermediate consumption of oil also entails a significant amount of indirect taxes. Consequently, tax revenue from indirect taxes is reduced. Likewise, higher excises for households lead to lower consumption levels of durables and linked non-durables (fuels). This lowers the revenue from particular indirect taxes, such as traffic taxes and the duties paid for the acquisition of cars. In addition, in the scenario of a federal energy tax increase with lump sum revenue recycling, investments are reduced. The most important supplier of the investment good is the construction sector (13). Since indirect taxes are relatively high in this sector, lower investments bring about a decrease in indirect tax revenue collected.

Second, detailed sectoral effects explain the impact on **subsidies** paid by the regional governments. A fixed proportion of total production cost of a sector is subsidized. Therefore, the total amount of subsidies paid varies with both the level and the cost of production. The subsidy expenses of the regional government of Brussels are 23.47 million € higher than in the baseline. To a large extent, this can be explained by the higher level and cost of production of the transport (14) and public (18) sectors in Brussel. Remark that the transport sector (14) in Brussels, which includes rail, metro, bus, taxi and freight traffic, is highly subsidized and therefore better protected against increases in production costs than firms in other regions. Consequently, the output of this sector and total subsidies paid by the regional government of Brussels increase in all scenarios. In Wallonia, production levels of transport and public sectors drop, leading to a lower total amount of subsidies.

Differences in indirect tax revenue and production subsidies are the main drivers of regional budgetary changes. Regional governments levy **lump sum taxes** (or pay out lump sum transfers in case of a positive budget difference with the baseline) to reach the level of surplus relative to nominal GDP in factor prices in the baseline. The first panel of table 5 shows that all three regional governments need to collect a lump sum tax to close the budget. This tax is particularly high in Brussels, the smallest region in terms of population. Therefore, disposable incomes and household consumption in this region are reduced, as mentioned before (see table 2).

Finally, the three components of the transfer of funds from the federal to the regional governments are displayed in table 5. Note that the changes in monetary flows caused by the **revenue sharing mechanism** are relatively small. Also remark that the total transfer from direct taxes and from VAT revenue does not change since it is based on a fixed envelope. The transfers from the direct tax revenue vary in accordance with relative household incomes. The redistribution of VAT revenue hardly varies across scenarios since the allocation is largely based on population numbers. The solidarity transfers mitigates divergences in regional incomes.

Note that a regional green tax shift in Flanders with lowered labour taxes (panel four) has a positive effect on the federal budget of 51.95 million € via increased employment, wages and households consumption (leading to higher tax income from direct and VAT taxes). In addition, the results displayed in table 5 illustrate how a federal policy reform affects regional governments' budgets when several policy instruments are taken into account. Furthermore, the effects indicate fiscal spillovers of one region's policy choices in neighbouring regions.

Federal gov. - Lump sum	***Federal Government***	***Regional Government Brussels***	***Flanders***	***Wallonia***
Transfers from Direct Tax revenue	0.00	-0.60	0.44	0.16
Transfers from VAT revenue	0.00	-0.03	0.02	0.01
Solidarity Transfers	0.68	0.76	-	-0.08
Indirect taxes	-	-5.14	-21.13	-20.82
Subsidies (-)	-	23.47	1.04	-26.30
Lump sum transfer (+) or tax (-)	358.00	-26.40	-20.36	-9.46

Federal gov. - Labour tax	***Federal***	***Brussels***	***Flanders***	***Wallonia***
Transfers from Direct Tax revenue	0.00	-0.64	0.60	0.04
Transfers from VAT revenue	0.00	-0.04	0.03	0.00
Solidarity Transfers	0.91	0.80	-	0.11
Indirect taxes	-	-1.38	-16.96	-19.01
Subsidies (-)	-	29.38	-1.61	-26.56
Lump sum transfer (+) or tax (-)	-	-24.23	1.60	1.24

Flemish gov. - Lump sum	***Federal***	***Brussels***	***Flanders***	***Wallonia***
Transfers from Direct Tax revenue	0.00	-1.14	2.36	-1.21
Transfers from VAT revenue	0.00	-0.06	0.13	-0.07
Solidarity Transfers	3.15	1.54	-	1.61
Indirect taxes	-	2.37	-31.95	4.53
Subsidies (-)	-	28.50	-39.37	18.84
Lump sum transfer (+) or tax (-)	33.83	-24.12	179.78	-7.78

Flemish gov. - Labour tax	***Federal***	***Brussels***	***Flanders***	***Wallonia***
Transfers from Direct Tax revenue	0.00	-1.29	3.68	-2.39
Transfers from VAT revenue	0.00	-0.07	0.21	-0.13
Solidarity Transfers	4.88	1.74	-	3.14
Indirect taxes	-	-6.80	-14.96	-1.44
Subsidies (-)	-	7.71	-10.29	5.82
Lump sum transfer (+) or tax (-)	51.95	-15.93	-	-16.35

Table 5: Public finance interactions: difference from the baseline in 2050, in million € 2005

4 Conclusions

The burden of energy taxes can differ significantly across regions. Studying tax incidence therefore requires a framework with sufficient regional detail. A bottom-up regional CGE model is developed for Belgium and applied to study federal and regional increases of oil excises, the largest environmental tax in Belgium in terms of revenue. Numerical results reveal several interesting findings. First, the impact of a harmonised tax increase in the whole country varies significantly across regions due to differences in sectoral composition. Particularly, production and employment in Wallonia decrease more than in other regions. Second, the stronger reduction in overall output in scenarios with lump sum revenue recycling compared with scenarios where labour taxes are reduced indicates that the former type of scenario imposes a heavier burden on industries. Carbon emissions can be reduced without lowering the country-wide level of production when the additional energy tax revenue is used to lower pre-existing distortionary labour taxes. Third, when the largest region in the country implements an environmental tax reform unilaterally, losses (in the lump sum recycling scenario) or gains (when labour taxes are reduced locally) appear to be exacerbated. This result points out the importance of a shared labour market with free mobility of workers. Fourth, the results illustrate that local tax policy in Flanders can spill over into neighbouring regions via mobility of workers, relocation of firms and changes in competitive position of industries. Fifth, the carbon emission reduction achieved by unilateral policy of Flanders may be partially offset by a carbon leakage effect in the other regions, where production, energy intensity and CO_2 emissions rise. However, when the regional government of Flanders uses the additional tax revenue to lower labour taxes locally, we find that emissions are lowered in all regions. Sixth, we illustrate how regions in a federation are interlinked via public finance mechanisms. Federal reforms have an impact on regional governments' budgets and vice versa. The solidarity mechanism and the redistribution of federal tax revenue between regions appear to be of minor importance for the tax reforms studied here. However, results indicate that interactions with other policy instruments, such as subsidies and indirect taxes on production, may be substantial.

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Appendix

A Consumption Structure and Categories

	Consumption Category
1	Food, Beverages and Tobacco
2	Clothing and Footwear
3	Housing and Water Charges
4	Fuels and Power
5	Housing Furniture and Operation
6	Heating and Cooking Appliances*
7	Medical Care and Health Expenses
8	Transport Equipment*
9	Operation of Transport Equipment
10	Purchased Transport
11	Telecommunication Services
12	Recreation, Entertainment, Culture, etc.
13	Other Services

* Durables

Table 6: Consumption Categories

B Derivation of the shadow price p_D

Divide the first order conditions

$$p_D \frac{\partial X_D}{\partial K} = p_K$$
$$p_D \frac{\partial X_D}{\partial LEM} = p_{LEM}$$

by each other to obtain

$$\frac{p_K}{p_{LEM}} = \left(\frac{\delta_K}{\delta_{LEM}} \frac{LEM}{K} \right)^{\frac{1}{\sigma_1}}$$

Then, we can express

$$LEM = \left(\frac{p_K}{p_{LEM}} \right)^{\sigma_1} \frac{\delta_{LEM}}{\delta_K} K$$

If we use this in the first order condition with respect to LEM and rewrite, we get

$$p_D = \left[\delta_K \left(p_K e^{tgk*t} \right)^{1-\sigma_1} + \delta_{LEM} p_{LEM}^{1-\sigma_1} \right]^{\frac{1}{1-\sigma_1}}$$

C Solving the consumer's problem

From the consumer's problem given by expressions (1) and (2), we can derive the demand functions for consumption C_t and leisure L_t. Writing the Lagrangian of the consumer's problem (with multiplier λ) and setting it's partial derivatives to consumption C_t and leisure L_t equal to 0 gives the first order conditions:

$$(1+stp)^{-t}\beta_C \frac{1}{C_t-\gamma_C} = \lambda(1+r)^{-t}p_{C,t} \tag{12}$$

$$(1+stp)^{-t}\beta_L \frac{1}{L_t-\gamma_L} = \lambda(1+r)^{-t}p_{L,t} \tag{13}$$

Rewriting these conditions for each t and summing over time t, we get:

$$\sum_t (1+r)^{-t}p_{C,t}C_t = \sum_t (1+stp)^{-t}\beta_C \frac{1}{\lambda} + \sum_t (1+r)^{-t}p_{C,t}\gamma_C$$

$$\sum_t (1+r)^{-t}p_{L,t}L_t = \sum_t (1+stp)^{-t}\beta_L \frac{1}{\lambda} + \sum_t (1+r)^{-t}p_{L,t}\gamma_L$$

Putting these expressions in the budget constraint (2), we obtain:

$$\sum_t (1+r)^{-t}(Y_{TR,t}+p_L\overline{L_t}) = \sum_t (1+r)^{-t}p_{C,t}C_t + \sum_t (1+r)^{-t}p_{L,t}L_t$$

$$\Leftrightarrow \sum_t (1+r)^{-t}(Y_{TR,t}+p_L\overline{L_t}) = \frac{1}{\lambda}\sum_t (1+stp)^{-t}(\beta_C+\beta_L) + \sum_t (1+r)^{-t}(p_{C,t}\gamma_C + p_{L,t}\gamma_L)$$

Solving for λ gives the value of the Langrange multiplier:

$$\lambda = \frac{\sum_t (1+stp)^{-t}(\beta_C+\beta_L)}{\sum_t (1+r)^{-t}(\underbrace{Y_{TR,t}+p_{L,t}\overline{L_t}} - p_{C,t}\gamma_C - p_{L,t}\gamma_L)} \tag{14}$$

Behaviour is based on myopic assumptions, such that the household decides on consumption and leisure given prices in the current period. We assume that the terms in the denominator of the above expression increase at a constant rate f (inflation). Furthermore remark that for a given year $y_{TR,t}+p_{L,t}\overline{L_t} = y_{DISP,t}+p_{L,t}L_t$, where y_{DISP} is the disposable income. Using this, the denominator becomes $\sum_t (1+r)^{-t}(1+f)^t(y_{DISP,0}+p_{L,0}L_0-p_{C,0}\gamma_C-p_{L,0}\gamma_L)$. We then replace the factor $\frac{1+r}{1+f}$ with $1+rr$, where rr is the real interest rate, and approximate $\sum_t (\frac{1}{1+rr})^t$ by $\frac{1}{rr}$ (this is exact for very large t) to obtain

$$\lambda = \frac{\frac{rr}{stp}(\beta_C+\beta_L)}{y_{DISP,0}+p_{L,0}L_0-p_{C,0}\gamma_C-p_{L,0}\gamma_L} \tag{15}$$

Now, expressing first order conditions (12) and (13) for the current time period ($t = 0$),

$$\begin{aligned} \beta_C &= \lambda p_C (C - \gamma_C) \\ \beta_L &= \lambda p_L (L - \gamma_L), \end{aligned}$$

and using expression (14) for the Langrange multiplier λ, we obtain consumption demand C and leisure demand L in a Linear Expenditure System (LES):

$$\begin{aligned} C &= \gamma_C + \frac{stp}{rr} \frac{\beta_C}{p_C} (y_{DISP} + p_L L - p_C \gamma_C - p_L \gamma_L) \\ L &= \gamma_L + \frac{stp}{rr} \frac{\beta_L}{p_L} (y_{DISP} + p_L L - p_C \gamma_C - p_L \gamma_L), \end{aligned}$$

where we have used $\beta_C + \beta_L = 1$.

To obtain expressions for the consumption of non-linked non-durable goods $C_{NLND,t}$ (with price $p_{ND,t}$) and the desired stock of durables $S_{DG,t}$, we solve the following optimization problem (for each period t):

$$\underset{C_{NLND,t}, S_{DG,t}}{Max} \; U_{C,t} = \sum_{NLND} \beta_{ND} \ln(C_{NLND,t} - \gamma_{ND}) + \sum_{DG} \beta_{DG} \ln(S_{DG,t} - \gamma_{DG})$$

$$s.t. \; p_{C,t} C_t = \sum_{ND} p_{ND,t} C_{NLND,t} + \sum_{DG} p_{DG,t} S_{DG,t}$$

Again, γ_{ND} and γ_{DG} are subsistence levels; β_{ND} and β_{DG} are share parameters. The value of C_t is derived above. The sets of non-linked non-durable goods and durable goods $NLND$ and DG respectively. Solving for $C_{NLND,t}$ and $S_{DG,t}$, we get the demand for each category of non-durable goods (11 categories) and for the desired stock of durables (2 categories):

$$C_{NLND,t} = \gamma_{ND} + \frac{\beta_{ND}}{p_{ND,t}} \sum_{ND} p_{ND,t} (C_{NLND,t} - \gamma_{ND}) \tag{16}$$

$$S_{DG,t} = \gamma_{DG} + \frac{\beta_{DG}}{p_{DG,t}} \sum_{ND} p_{ND,t} (C_{NLND,t} - \gamma_{ND}) \tag{17}$$

where we have used $\sum_{NLND} \beta_{ND} = 1$. To obtain the total demand for non-durables, we need to add the demand for non-durables that is used for the operation of durables. The consumption of linked non-durables increases with the stock of durables and is given by

$$C_{LND,t} = S_{DG,t} \left[\gamma_{LND} + \alpha_{LND} \left(\frac{p_{C,t}}{p_{LND,t}} \right)^{\sigma_{LND}} \right] \tag{18}$$

$$C_{ND,t} = C_{NLND,t} + C_{LND,t} \tag{19}$$

A minimum consumption of linked non-durable consumption is assumed. Parameter γ_{LND} reflects this fixed part of consumption. The second term represents the flexible consumption of linked non-durables, where α_{LND} is a scale parameter that follows from the calibration. Demand for linked non-durables furthermore depends on a cost-of-living index $p_{C,t}$ (derived as the ratio between value and volume of consumption, see section H), the price of linked non-durables $p_{LND,t}$ (including VAT and energy taxes) and price elasticity σ_{LND} (fixed exogenously). Given the stock of durables in the previous period $S_{DG,t-1}$, the desired stock of durables $S_{DG,t}$ and a five year time period, the additional stock of durables $\Delta S_{DG,t}$ to acquire yearly[8] is defined by

$$S_{DG,t} = (1 - d_H)^5 S_{DG,t-1} + \frac{1 - (1 - d_H)^5}{d_H} \Delta S_{DG,t}$$

Finally, total demand for the 13 commodities is transformed into demand for the outputs of 18 industry branches by using the consumption matrix, shown in table 7 on the next page. We denote an element of this matrix with $tcc_{br,com}$ (for technical coefficient for consumption, connecting industry branches with commodities).

[8] If $S_n = (1 - d)^4 + (1 - d)^3 + (1 - d)^2 + (1 - d) + 1$
then $(1 - d)S_n = (1 - d)^5 + (1 - d)^4 + (1 - d)^3 + (1 - d)^2 + (1 - d)$
so $S_n - (1 - d)S_n = 1 - (1 - d)^5$
and $S_n = \frac{1-(1-d)^5}{d}$

	Consumption categories												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Industry Branch													
1	10.31	0	0	0.25	0	0	0	0	0	0	0	1.17	0.01
2	0	0	0	0.54	0	0	0	0	0	0	0	0	0
3	0	0	0	9.97	0	0	0	0	36.58	0	0	0	0
4	0	0	0	22.91	0	0	0	0	0	0	0	0	0
5	0	0	0	48.67	0	0	0	0	0	0	0	0	0
6	0	0.02	0	0	8.64	0.10	0	0	0	0	0	0.09	0.50
7	0.30	0	0.77	0	6.48	0	18.10	0	0.17	0	0	0.35	3.13
8	1.42	0	0.33	0	3.86	0	0.74	0	0	0	0	0.13	1.85
9	0	0	0.29	0	18.93	78.70	9.00	0	0.29	0	0	5.21	0.23
10	0	0	0	0	0.09	0	0.19	43.89	0.57	0	0	0.09	0
11	0	0.11	0.70	0	20.15	0	0.34	0	3.28	0	0	11.82	0.24
12	58.10	52.15	0	0	3.52	0	4.61	0	0	0	0	0.76	0.07
13	0	0	1.50	0	0	0	0	0	0	0	0	0	0
14	0.03	0.07	0.01	0.06	0.08	0.06	0.05	0.04	0.04	74.13	0	2.77	0.05
15	0.03	0.06	0.01	0.05	0.08	0.06	0.05	0.04	0.04	25.87	0	0.05	0.05
16	1.28	2.48	0.52	2.04	3.01	2.37	1.84	1.41	1.51	0	0	2.02	43.57
17	27.81	40.39	95.58	14.38	27.04	17.41	13.47	53.86	56.36	0	100	58.53	13.72
18	0.71	4.73	0.29	1.12	8.12	1.30	51.61	0.77	1.16	0	0	17.01	36.59

Table 7: Consumption Matrix; gives the contribution of industry outputs (%) for each consumption category.

D Deriving optimal factor demands

We derive optimal factor demands solving the profit maximisation problem. Substituting the constraint (6) into the objective function (5) and leaving out subscript t for simplicity, we get:

$$\pi = p_D \left[\delta_K^{\frac{1}{\sigma_1}} K^{\frac{\sigma_1 - 1}{\sigma_1}} + \delta_{LEM}^{\frac{1}{\sigma_1}} * LEM^{\frac{\sigma_1 - 1}{\sigma_1}} \right]^{\frac{\sigma_1}{\sigma_1 - 1}} - p_K K - p_{LEM} LEM$$

We obtain the factor demands by rewriting the first order conditions. For the demand for capital, we get:

$$\frac{\partial \pi}{\partial K} = p_D \frac{\partial X_D}{\partial K} - p_K = 0$$

$$\Leftrightarrow \frac{p_K}{p_D} = \frac{\sigma_1}{\sigma_1 - 1} X_D^{\frac{1}{\sigma_1}} \delta_K^{\frac{1}{\sigma_1}} \frac{\sigma_1 - 1}{\sigma_1} K^{-\frac{1}{\sigma_1}}$$

$$\Leftrightarrow \frac{p_K}{p_D} = X_D^{\frac{1}{\sigma_1}} \delta_K^{\frac{1}{\sigma_1}} K^{-\frac{1}{\sigma_1}}$$

$$\Leftrightarrow K = \left(\frac{p_D}{p_K} \right)^{\sigma_1} X_D \delta_K$$

And the demand for Labour-Energy-Materials:

$$\frac{\partial \pi}{\partial LEM} = p_D \frac{\partial X_D}{\partial LEM} - p_{LEM} = 0$$

$$\Leftrightarrow LEM = \left(\frac{p_D}{p_{LEM}} \right)^{\sigma_1} X_D \delta_{LEM}$$

On the second level, we solve a cost minimisation problem:

$$\underset{E_t, L_{D,t}, M_t}{Min} \; p_{LD,t} L_{D,t} + p_{E,t} E_t + p_{M,t} M_t \tag{20}$$

$$s.t. \; LEM_t = \left[\delta_{LD}^{\frac{1}{\sigma_2}} (\zeta L_{D,t})^{\frac{\sigma_2 - 1}{\sigma_2}} + \delta_E^{\frac{1}{\sigma_2}} E_t^{\frac{\sigma_2 - 1}{\sigma_2}} + \delta_M^{\frac{1}{\sigma_2}} M_t^{\frac{\sigma_2 - 1}{\sigma_2}} \right]^{\frac{\sigma_2}{\sigma_2 - 1}} \tag{21}$$

where ζ is the service per hour of labour. This is a measure for labour productivity. The price of labour, energy and materials in time t is denoted by $p_{LD,t}$, $p_{E,t}$ and $p_{M,t}$ respectively. As before, δ_{LD}, δ_E and δ_M are scale parameters and σ_2 is the substitution elasticity. Solving the problem in

(20)-(21), we obtain the factor demands for labour $L_{D,t}$, energy E_t and materials M_t:

$$L_{D,t} = \left(\frac{p_{LEM,t}}{p_{LD,t}}\right)^{\sigma_2} \frac{1}{\zeta} LEM_t \delta_{LD} \tag{22}$$

$$E_t = \left(\frac{p_{LEM,t}}{p_{E,t}}\right)^{\sigma_2} LEM_t \delta_E \tag{23}$$

$$M_t = \left(\frac{p_{LEM,t}}{p_{M,t}}\right)^{\sigma_2} LEM_t \delta_M \tag{24}$$

The demand for these production factors depends on relative prices, the possibilities for substitution and the demand for the LEM-aggregate (one level up in the nested structure). The demand for fuels F_t, electricity EL_t, coal $F_{coal,t}$, oil $F_{oil,t}$, gas $F_{gas,t}$ and intermediates IO_t is derived in a similar way. The resulting factor demands are shown below.

The demand for fuels F_t, electricity EL_t, coal $F_{coal,t}$, oil $F_{oil,t}$, gas $F_{gas,t}$ and intermediates IO_t:

$$\begin{aligned}
F_t &= \left(\frac{p_{E,t}}{p_{F,t}}\right)^{\sigma_3} E_t \delta_F \\
EL_t &= \left(\frac{p_{E,t}}{p_{EL,t}}\right)^{\sigma_3} E_t \delta_{EL} \\
F_{coal,t} &= \left(\frac{p_{F,t}}{p_{coal,t}}\right)^{\sigma_4} F_t \delta_{F_{coal}} \\
F_{oil,t} &= \left(\frac{p_{F,t}}{p_{oil,t}}\right)^{\sigma_4} F_t \delta_{F_{oil}} \\
F_{gas,t} &= \left(\frac{p_{F,t}}{p_{gas,t}}\right)^{\sigma_4} F_t \delta_{F_{gas}} \\
IO_t &= \left(\frac{p_{M,t}}{p_{IO,t}}\right)^{\sigma_5} M_t \delta_{IO}
\end{aligned}$$

E Investment

To clarify the investment decision, we start from the desired capital stock, given by equation (7), to express the desired capital stock for the next period:

$$K_{t+1,desired} = X_{D,\exp} \left(\frac{p_{D,\exp}}{p_{K,opt}} \right)^{\sigma_1} \delta_K$$

The expected production in the next period, $X_{D,\exp} = X_{D,t}(1 + stgr)$, depends on the growth expectation (by sector) $stgr$. Firm behaviour is myopic in the sense that the expected prices equal the prices of the current period, $p_{D,\exp} = p_{D,t}$. For the future price of capital we use the optimal long-run cost of capital derived according to the Ando-Modiglian formula (Ando, Modigliani, Rasche, and Turnovsky 1974): $p_{K,opt} = p_{inv}(rr + d)$. In this expression, rr is the real interest rate and d denotes depreciation. The price of investment, expressed for all sectors with subscript br (and pr) for a branch, is $p_{inv,br,t} = \sum_{pr} tci_{pr,br}(1+\tau_{IT})p_{Y,t}$. The parameter $tci_{pr,br}$ represents the technical coefficient from the investment matrix. This matrix maps investment demand to demand for sector outputs with endogenous price $p_{Y,t}$, including indirect taxes τ_{IT}. To obtain the expression for investment I_t, we subtract the remaining value of this period's capital from the desired capital stock in the next period:

$$\begin{aligned}
I_t &= K_{t+1,desired} - (1-d)K_t \\
&= X_{D,t}(1+stgr)\left(\frac{p_{D,\exp}}{p_{inv,t}(rr+d)}\right)^{\sigma_1} \delta_K - (1-d)K_t \\
&= K_t \left[\left(\frac{p_{K,t}}{p_{D,t}}\right)^{\sigma_1} (1+stgr) \left(\frac{p_{D,\exp}}{p_{inv,t}(rr+d)}\right)^{\sigma_1} - (1-d) \right] \\
&= K_t \left[(1+stgr) \left(\frac{p_{K,t}}{p_{inv,t}(rr+d)}\right)^{\sigma_1} - (1-d) \right] \qquad (25)
\end{aligned}$$

We take a period length of five years, which means that firms decide on the yearly investment once every five years. Therefore the capital stock in the next period is given by[9]

$$\begin{aligned}
K_{t+1} &= (1-d)^5 K_t + (1-d)^4 I_t + (1-d)^3 I_t + (1-d)^2 I_t + (1-d) I_t + I_t \\
&= (1-d)^5 K_t + \frac{1-(1-d)^5}{d} I_t
\end{aligned}$$

The aggregate level of investments determines the total capital stock in the next period, which is the supply of capital stock. The investment matrix (containing $tci_{pr,br}$) transforms the investment demand into demand by sectoral outputs and is shown in table 8 on the next page.

[9] If $S_n = (1-d)^4 + (1-d)^3 + (1-d)^2 + (1-d) + 1$
then $(1-d)S_n = (1-d)^5 + (1-d)^4 + (1-d)^3 + (1-d)^2 + (1-d)$
so $S_n - (1-d)S_n = 1 - (1-d)^5$
and $S_n = \frac{1-(1-d)^5}{d}$

	is delivered by industry branch								
	1	3	6	9	10	11	13	17	18
Investment of industry branch									
1	16.37	0.005	1.07	43.79	1.73	0.10	20.32	16.59	0.02
2	0	0.01	9.03	46.15	2.19	0.76	14.19	27.59	0.08
3	0	0.01	9.03	46.15	2.19	0.76	14.19	27.59	0.08
4	0	0.01	9.03	46.15	2.19	0.76	14.19	27.59	0.08
5	0	0.01	5.34	45.84	2.28	0.59	16.95	28.97	0.03
6	0	0.01	5.48	59.37	3.56	2.30	6.64	22.57	0.07
7	0	0.02	9.03	51.75	3.29	1.08	11.25	23.48	0.10
8	0	0.02	1.69	60.91	5.61	1.77	7.92	21.98	0.09
9	0	0.09	2.20	48.85	7.89	1.76	8.84	29.88	0.48
10	0	0.04	5.68	65.20	1.51	1.96	2.66	22.73	0.21
11	0	0.03	2.11	56.04	4.87	2.99	9.27	24.53	0.16
12	0	0.03	2.66	54.58	8.26	3.92	9.48	20.88	0.17
13	0	0.01	2.75	32.68	18.58	0.65	27.01	18.30	0.03
14	0	0.00	1.17	7.73	73.57	0.84	10.72	5.96	0.01
15	0	0.67	1.13	35.78	39.79	6.69	0.80	11.62	3.52
16	0	0.06	0.92	10.95	30.29	6.93	9.11	41.41	0.33
17	0	0.00	1.30	13.82	7.10	2.76	56.68	18.32	0.02
18	0	0.01	2.08	19.98	9.41	3.65	41.33	20.33	3.21

Table 8: Investment Matrix; gives the deliveries of industry branches (%) for investments of all industry branches.

F Statistical classification of products by activity (CPA codes)

CPA	*Category*	*CGE*	*Micro*
01	Products of agriculture, hunting and related services	1	1
02	Products of forestry, logging and related services	1	1
05	Fish and other fishing products; services incidental of fishing	1	1
10	Coal and lignite; peat	2	2
11	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying	4	2
12	Uranium and thorium ores	5	2
13	Metal ores	6	2
14	Other mining and quarrying products	8	2
15	Food products and beverages	12	2
16	Tobacco products	12	2
17	Textiles	12	2
18	Wearing apparel; furs	12	2
19	Leather and leather products	12	2
20	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials	11	2
21	Pulp, paper and paper products	8	2
22	Printed matter and recorded media	11	2
23	Coke, refined petroleum products and nuclear fuels	3	2
24	Chemicals, chemical products and man-made fibres	7	2
25	Rubber and plastic products	11	2
26	Other non-metallic mineral products	8	2
27	Basic metals	6	2
28	Fabricated metal products, except machinery and equipment	6	2
29	Machinery and equipment n.e.c.	9	2
30	Office machinery and computers	9	2
31	Electrical machinery and apparatus n.e.c.	9	2
32	Radio, television and communication equipment and apparatus	9	2
33	Medical, precision and optical instruments, watches and clocks	9	2
34	Motor vehicles, trailers and semi-trailers	10	2
35	Other transport equipment	10	2
36	Furniture; other manufactured goods n.e.c.	11	2
37	Secondary raw materials	11	2
40	Electrical energy, gas, steam and hot water	5	2
41	Collected and purified water, distribution services of water	18	2
45	Construction work	13	3
50	Trade, maintenance and repair services of motor vehicles; retail sale of automotive fuel	17	4
51	Wholesale trade and commission trade services, except of motor vehicles	17	4
52	Retail trade services, except of motor vehicles; repair services of personal and household goods	17	4
55	Hotel and restaurant services	17	5
60	Land transport; transport via pipeline services	14	6
61	Water transport services	15	6
62	Air transport services	15	6
63	Supporting and auxiliary transport services; travel agency services	17	6
64	Post and telecommunication services	17	6
65	Financial intermediation services, except insurance and pension funding services	16	7
66	Insurance and pension funding services, except compulsory social security services	16	7
67	Services auxiliary to financial intermediation	16	7
70	Real estate services	17	8
71	Renting services of machinery, equipment without operator and of personal and household goods	17	8
72	Computer and related services	17	8
73	Research and development services	17	8
74	Other business services	17	8
75	Public administration and defence services; compulsory social security services	18	9
80	Education services	18	10
85	Health and social work services	18	11
90	Sewage and refuse disposal services, sanitation and similar services	18	12
91	Membership organisation services n.e.c.	18	12
92	Recreational, cultural and sporting services	18	12
93	Other services	18	12
95	Private households with employed persons	18	12

G Trade

To obtain domestic and import demand, we solve the following problem for each industrial sector:

$$\underset{Y_{DOM,t},Z_t}{Max} \; p_{Y,t}Y_t - p_{DOM,t}Y_{DOM,t} - p_{Z,t}Z_t \tag{26}$$

$$s.t. \; Y_t = \alpha_A \left[\delta_{DOM} Y_{DOM,t}^{\frac{\sigma_Z - 1}{\sigma_Z}} + (1-\delta_{DOM}) Z_t^{\frac{\sigma_Z - 1}{\sigma_Z}} \right]^{\frac{\sigma_Z}{\sigma_Z - 1}} \tag{27}$$

We denote the price of the composite good with $p_{Y,t}$. Domestic prices $p_{XD,t}$ follow from the goods market equilibrium. Import prices $p_{Z,t} = p_{W,t}(1 + t_{DUT})$ are exogenous, since Belgium is a small country, and depend on import duties t_{DUT} and world prices $p_{W,t}$. Parameter α_A is a scale parameter for the Armington specification. The elasticity of substitution between domestically produced goods and imports is captured by σ_Z. Finally, δ_{DOM} is a scale parameter, calibrated as the share of domestic goods in the demand for composite good Y_t. Substituting the constraint (26) into the objective function 27 and deriving with respect to $Y_{DOM,t}$ and Z_t, we get

$$\begin{aligned} Y_{DOM,t} &= Y_t * \alpha_A^{\sigma_Z - 1} * \delta_{DOM}^{\sigma_Z} \left(\frac{p_{Y,t}}{p_{DOM,t}} \right)^{\sigma_Z} \\ Z_t &= Y_t * \alpha_A^{\sigma_Z - 1} * (1-\delta_{DOM})^{\sigma_Z} \left(\frac{p_{Y,t}}{p_{Z,t}} \right)^{\sigma_Z} . \end{aligned}$$

In the same fashion, we model **exports** EXP to the rest of the world as

$$EXP_t = Y_{W,t} * \alpha_W \left(\frac{p_{W,t}}{p_{EXP,t}} \right)^{\sigma_{EXP}}$$

with exogenous world demand $Y_{W,t}$ and price elasticity of export demand σ_{EXP}. Exports of an industry increase, *ceteris paribus*, when this sector becomes more competitive, i.e. $\frac{p_{W,t}}{p_{EXP,t}}$ increases. Remark that industry branches 2 (coal), 4 (goas), 5 (electricity), 13 (construction) and 18 (non-market services) are treated as 'non-import-substitutables'. For these sectors we do not specify an Armington function. Price formation for these branches is slightly different and is discussed below.

Industry branches 2 (coal), 4 (gas), 5 (electricity), 13 (construction) and 18 (non-market services) are treated as 'non-import-substitutables'. For these sectors, we do not specify the Armington function. Instead, we assume imports are a fixed fraction β_{NT} of domestic demand. Import demand in the 'non-import-substitutable' sectors is more likely to be driven by other considerations than the relation between the domestic and world price, such as institutional settings (e.g. contracts in the gas market). The equilibrium condition for goods is then

$$\begin{aligned} X_{D,t} &= Y_t + EXP_t - IMP_t \\ &= (1-\beta_{NT})Y_t + EXP_t \end{aligned}$$

This condition determines the price $p_{DOM,t}$. Furthermore, $p_{Y,t} = p_{DOM,t}$. Since for each unit consumed, a fraction β_{NT} will be imported, we can write $p_{DOM,t}$ as

$$p_{DOM,t} = (1 + \tau_{SUB})(1 - \beta_{NT})p_{D,t} + p_{Z,t}\beta_{NT}, \tag{28}$$

the import price $p_{Z,t}$ is the same as stated above. τ_{SUB} is subsidy rate. Unit production cost $p_{D,t}$ is then defined by expression (28) and equal to

$$p_{D,t} = \left(\frac{p_{DOM,t} - p_{Z,t}\beta_{NT}}{1 - \beta_{NT}}\right)\frac{1}{1 + \tau_{SUB}}$$

The export price is equal to

$$p_{EXP,t} = \frac{p_{DOM,t} - p_{Z,t}\beta_{NT}}{1 - \beta_{NT}}$$

H Model closure and prices

This section explains the macro-closure of the model. Furthermore, we show how prices are derived. First, we clarify the **savings-investment rule** with a stylized example using a structure analogous to our model (but leaving out several details, e.g. other government revenue sources). Consider production $F(K, L_D, Z)$ with capital K, labour L_D and imports Z as inputs. The zero profit condition is then

$$p_D X_D = p_K K + p_L L_D + p_Z Z + T_F,$$

where p_Z is the price of imports and T_F equals the taxes paid by firms. Using the condition that all (capital and labour) income (after taxes T_{HH}) is either consumed or saved, we get

$$p_D X_D = \underbrace{p_D C + s(p_K K + p_L L_D) + T_H}\, + p_Z Z + T_F$$

Taking into account the equilibrium on the goods market, production equals consumption or $X_D = G + C + I + EXP$, where we denote government consumption with G and exports with EXP, we obtain

$$p_D I + p_D G + p_D EXP = p_Z Z + T_{HH} + T_F + S_{priv},$$

where private savings $S_{priv} = s(p_K K + p_L L_D)$. Then, inserting the government budget constraint, $p_D G + S_{pub} = T_{HH} + T_F$, we get

$$\underbrace{p_D I}_{Investments} + \underbrace{p_D EXP - p_Z Z}_{Trade\ Balance} = \underbrace{S_{pub} + S_{priv}}_{Savings},$$

where S_{pub} represent public savings. Investments are determined endogenously as explained in appendix E. Imports and exports are derived in appendix G. In the scenarios discussed in section 3, we will keep the level of government surplus, relative to GDP, equal to the level in the baseline. In summary, we obtain the model closure implicitly by imposing four conditions: the zero profit condition, complete use of income, the equilibrium on the goods market and the government budget constraint. Since we model a common goods market for Belgium, the savings-investment relationship need not hold on the regional level, which seems a plausible assumption (Partridge and Rickman 1998). Total investments are derived from firm choices as explained above. In addition, we assume that these investments are partly done by households (investment in sector 13: Building and Construction) and by the government (in government sector 18: Non-market Services). A share of capital rents stays with the firms, which explains firm savings. In conclusion, the sum savings minus investments ove all agents (households, firms, governments and the rest of the world) will alway be zero.

The prices faced by the household are given by:

$$
\begin{aligned}
p_{C,t} &= \frac{p_{NLND,t}C_{NLND,t} + p_{LND,t}C_{LND,t} + (1+\tau_{VAT})(1+\tau_{it})tcc_{br,com}p_Y \Delta S_{DG,t}}{C_{ND,t} + \Delta S_{DG,t}} \\
p_{L,t} &= (1-\tau_{SS,H})(1-\tau_{DT})w_t \\
p_{NLND,t} &= (1+\tau_{VAT})(1+\tau_{it})tcc_{br,com}p_{Y,t} \\
p_{LND,t} &= (1+\tau_{VAT})\left[(1+\tau_{it})tcc_{br,com}p_{Y,t} + \tau_{en}\frac{p_{c,t}}{p_{c,2005}}\varphi_{HH}\theta_{HH}\right] \\
p_{DG,t} &= (1+\tau_{VAT})(1+\tau_{it})(rr+d_H)tcc_{br,com}p_{Y,t} + \frac{C_{LND,t}}{S_{DG,t}}p_{LND,t}
\end{aligned}
$$

Note that commodity prices $p_{NLND,t}$, $p_{LND,t}$ and $p_{DG,t}$ (13 commodities) are derived from prices $p_{Y,t}$ by sector (18 branches) using the elements $tcc_{br,com}$ from the consumption matrix. Important for our study is the energy tax τ_{en} on the consumption of non-durables that is linked to the use of durables. This tax is of the excise type, so it is a tax per volume. It is updated with consumption price changes and multiplied with a share of energy use φ_{HH} and a conversion factor θ_{HH}. More details on these two parameters are provided in appendix J. Furthermore, received wages are affected by households' social security contributions $\tau_{SS,H}$ and direct taxes τ_{DT}, whereas consumption prices are influenced by value added taxes τ_{VAT} and indirect taxes τ_{it}. The price of durable goods $p_{DG,t}$ consists of two parts. The first term reflects the cost for holding the durable (including taxes and opportunity cost rr and depreciation d_H). The second term is included for the use of the durable. Firms take into account the following factor prices:

$$
\begin{aligned}
p_{LEM,t} &= \left[\delta_{LD}\left(\frac{1}{\zeta}p_{LD,t}\right)^{1-\sigma_2} + \delta_M p_{M,t}^{1-\sigma_2} + \delta_E p_{E,t}^{1-\sigma_2}\right]^{\frac{1}{1-\sigma_2}} \\
p_{LD,t} &= \frac{\Theta w_t}{1-\tau_{SS,F}} \\
p_{E,t} &= \left[\delta_{EL}p_{EL,t}^{1-\sigma_3} + \delta_F p_{F,t}^{1-\sigma_3}\right]^{\frac{1}{1-\sigma_3}} \\
p_{M,t} &= \left(\sum_M \delta_{IO}\left[(1+\tau_{it})p_{Y,t}\right]^{1-\sigma_5}\right)^{\frac{1}{1-\sigma_5}}
\end{aligned}
$$

Note that the price of the aggregate labour-energy-materials bundle $p_{LEM,t}$ is the shadow price of constraint (21). The labour cost for firms $p_{LD,t}$ is influenced by firms' social security contributions $\tau_{SS,F}$ and by the sectoral differentiation in wage, governed by the fixed parameter Θ. This parameter Θ is fixed and is calculated as the price of labour per industry branch relative to the average wage across industries w_t for the base year. Energy prices $p_{E,t}$ depend on prices of and substitution between electricity and fuels. The price of the materials aggregrate $p_{M,t}$ is determined by prices p_Y of outputs by branch and the substitution possibilities. A similar structure applies for the prices on for production factors on lower levels on the nested structure. These are shown below.

$$\begin{aligned}
p_{F,t} &= \left[\delta_{coal} p_{coal,t}^{1-\sigma_4} + \delta_{oil} p_{oil,t}^{1-\sigma_4} + \delta_{gas} p_{gas,t}^{1-\sigma_4}\right]^{\frac{1}{1-\sigma_4}} \\
p_{EL,t} &= (1+\tau_{it}) p_{Y,t} \\
p_{coal,t} &= (1+\tau_{it}) p_{Y,t} \\
p_{oil,t} &= (1+\tau_{it}) p_{Y,t} + \tau_{EN} \frac{p_{c,t}}{p_{c,2005}} \varphi_F \theta_F \\
p_{gas,t} &= (1+\tau_{it}) p_{Y,t}
\end{aligned}$$

To obtain the price of oil we include the amount of excises paid. This amount is added to the energy price because the excise tax τ_{EN} is a tax per volume. We index the excise duty by changes in consumption prices to keep it constant in real terms. Furthermore, we add the parameter φ_F for the share of energy use of oil by sector, since excises are not levied on non-energetic oil consumption (relevant for instance in the chemical sector). Conversion factor θ_F transforms the tax per petajoule to a tax per volume. More details on parameters φ_F and θ_F can be found in appendix J. Note that gas prices are not explicitly linked to oil prices, which may be the case in reality. A final set of prices is influenced by interaction with the rest of the world:

$$\begin{aligned}
p_{D,t} &= (p_{DOM,t} - p_{Z,t}\beta_{NC}) \frac{1}{1+\tau_{SUB}} \\
p_{Z,t} &= (1+\tau_{DUT}) p_{W,t} \\
p_{W,t} &= (1+g_t)^5 p_{W,t-1} \\
p_{Y,t} &= \frac{1}{\alpha_A}\left[\delta_{DOM}^{\sigma_Z} p_{DOM,t}^{1-\sigma_Z} + (1-\delta_{DOM})^{\sigma_Z} p_{Z,t}^{1-\sigma_Z}\right]^{\frac{1}{1-\sigma_Z}} \\
p_{EXP,t} &= p_{DOM,t}
\end{aligned}$$

where $p_{D,t}$ is the shadow (or dual) price of constraint (6) and reflects the unit production cost. Without taxes, subsidy rate τ_{SUB} and imports and under perfect competition, unit production cost would equal consumption prices. We assume that a share of production β_{NC} is non-competitive and has to be imported. Import prices $p_{Z,t}$ depend on import duties τ_{DUT} and on world prices. These world prices $p_{W,t}$ are exogenous and are growing at an exogenous rate g_t (which differs between branches). Price $p_{Y,t}$ is the shadow price of constraint (27) and depends on domestic and import prices and the Armington elasticity σ_Z. Export prices $p_{EXP,t}$ equal domestic prices $p_{DOM,t}$, since we assume there are no trade costs. Remark that some sectors are specified as 'non-import-substitutable'. For the goods market equilibrium and the price formation in these sectors, we refer to appendix G.

I Calibration and data

In the **calibration**, parameter values are fixed such that the model outcome reflects the data in the base year 2005. In our case, the calibration procedure attaches values to the share parameters (β's), the subsistence levels (γ's), the scale parameters (δ's and α's), tax rates (τ's) labour productivity ζ and the sectoral differentiation in wages Θ. The details of the calibration are illustrated in this section by deriving expressions for β_C and $\beta_{L,}$ γ_C and γ_L, δ_K and δ_{LEM}, direct tax rate on households τ_{DT} and the labour productivity ζ. The energy taxes τ_{en} and τ_{EN}, carbon emissions, the parameters for the share of energy use φ_F and φ_{HH} and the conversion factors θ_F and θ_{HH} are clarified in appendix J. The resulting own price elasticities are shown in table 13.

If a CGE model is to generate trustworthy results, it must rely on consistent **data**. Mercenier and Yeldan (1999) emphasize that the quality of the data is a crucial aspect for policy analysis in developing countries. The authors' remarks may also apply to regional CGE analyses, because regional data is often harder to find than data on the national level. The most important data input for a CGE model is the Social Accounting Matrix (SAM). Its rows represent revenues, columns reflect expenditures. The regional Social Accounting Matrices have been constructed by combining several data sources in a consistent way. Table 11 presents the origin of each data source used. A SAM consists of four parts. The first part of the SAM (upper left) reflects **intermediate demand** and has been constructed by updating (from 2003 to 2005) and aggregating (into 18 industry branches) regional input-output tables. The second quadrant (upper right) contains **final demand** for industry outputs by households, governments and the rest of the world (exports). The row sum across the first two quadrants is equivalent to the goods market clearance from expression (11). The third part (lower left) covers primary **inputs** in the production proces (labour and capital), taxes and subsidies. Data on commuting, population, wages and employment are used to derive regional labour input. The use of energy balances for the calibration of energy taxes is explained in appendix J. Factor market clearance, as in expressions (9) and (10), corresponds with row sums of labour and capital inputs. The sum of a column across quadrant one and three matches the zero profit condition for any industry branch. Finally, the fourth section of the SAM (lower right) comprises **transfers** between agents. This part has been constructed using household and regional and federal government accounts. The regional SAM for Flanders is (partially) shown in table 14.

Furthermore, some parameters are given a value exogenously, based on reasonable parameter variables found in empirical literature. Table 9 shows the values of the substitution elasticities by industry branch.

Industry Branch	***Exogenous elasticities*** σ_1	σ_2	σ_3	σ_4	σ_5	σ_Z	σ_{EXP}
1	0.4	0.5	0.4	0.6	0.2	1.2	1.4
2	0.4	0.5	0.4	0.1	0.1	0.6	0.6
3	0.5	0.5	0.4	0.1	0.1	0.6	0.6
4	0.5	0.5	0.4	0.1	0.1	0.6	0.6
5	0.5	0.5	0.4	0.9	0.1	0.6	0.6
6	0.5	0.5	0.4	0.9	0.5	1.5	2.2
7	0.5	0.5	0.4	0.9	0.5	1.5	2.2
8	0.5	0.5	0.4	0.9	0.5	1.5	2.2
9	0.5	0.5	0.4	0.6	0.3	1.5	2.2
10	0.5	0.5	0.4	0.6	0.3	1.5	2.2
11	0.4	0.5	0.4	0.6	0.3	1.5	2.2
12	0.4	0.5	0.4	0.6	0.3	1.7	2.5
13	0.4	0.5	0.4	0.6	0.3	0.6	1.4
14	0.4	0.5	0.4	0.6	0.3	0.6	1.4
15	0.4	0.5	0.4	0.4	0.1	1.2	2.2
16	0.4	0.5	0.4	0.6	0.3	0.6	1.4
17	0.4	0.5	0.4	0.6	0.3	0.6	1.4
18	0.4	0.5	0.4	0.6	0.3	0.4	0.6

Table 9: Values for substitution elasticities

Demographic changes are included by increasing the population as projected by Eurostat. Total population numbers are used to update the total time endowment $\overline{L_t}$. Moreover, domestic economic growth expectation $stgr$, needed for the investment decision, is assumed to be 1,5% for branches 1-12 (goods) and 2,5% for branches 13-18 (services). In addition, we assume world demand Y_W grows with a yearly rate of 1% in coal, oil and gas industries (branches 2-4), 3% in the goods industries (branches 1, 5-13 and 15) and 5% in the service sectors (branches 14 and 16-18). Table 10 below shows the values of remaining parameters.

Parameter	***Value***
stp	0.056
rr	0.0625
σ_{LND}	0.7
d_H	0.05
d	0.05

Table 10: Other parameters

Next, we present some details on the calibration of the model parameters (for the base year, so subscript t is not shown). We illustrate the calibration of the β's, γ's and δ's by deriving expressions for β_C and β_L, γ_C and γ_L and δ_K and δ_{LEM}. Furthermore, we comment on the calibration of direct tax rate on households τ_{DT} and the labour productivity ζ

First, we show how the parameters β_C **and** β_L are calibrated.

From equation (4) for leisure L we obtain

$$L = \gamma_L + \frac{stp}{rr}\frac{\beta_L}{p_L}(p_L\overline{L} + y_{TR} - p_C\gamma_C - p_L\gamma_L)$$

Now we can derive the leisure supply elasticity $\epsilon_L = \frac{\partial L}{\partial p_L}\frac{p_L}{L}$:

$$\epsilon_L = -\frac{stp}{rr}\beta_L\frac{y_{TR} - p_C\gamma_C}{p_L L}$$

Therefore, the elasticity of labour supply $\epsilon_{LS} = -\epsilon_L\frac{p_L}{L_S}$ can be written as

$$\epsilon_{LS} = \frac{stp}{rr}\beta_L\frac{y_{TR} - p_C\gamma_C}{p_L L_S}$$

Rewriting this equation we get an expression for β_L:

$$\beta_L = \frac{\epsilon_{LS} p_L L_S}{y_{TR} - p_C\gamma_C}\frac{rr}{stp} \tag{29}$$

Variables p_L, L_S and y_{TR} are known from available data and ϵ_{LS} is fixed exogenously. Furthermore, we assume $\frac{p_C\gamma_C}{y_{TR}} = 0,2$ to fix $p_C\gamma_C$. The remaining unknown factor is $\frac{stp}{rr}$. Using the expressions for consumption and leisure demand, (3) and (4), we obtain

$$\begin{aligned} p_C C + p_L L &= p_C\gamma_C + p_L\gamma_L + \frac{stp}{rr}(y_{DISP} + p_L L - p_C\gamma_C - p_L\gamma_L) \\ &= \left(1 - \frac{stp}{rr}\right)(p_C\gamma_C + p_L\gamma_L) + \frac{stp}{rr}(y_{DISP} + p_L L) \end{aligned}$$

Assuming $p_C\gamma_C + p_L\gamma_L$ is a fixed fraction of $y_{DISP} + p_L L$ and rewriting, we get an expression for $\frac{stp}{rr}$:

$$\frac{stp}{rr} = \frac{p_C C + p_L L - p_C\gamma_C - p_L\gamma_L}{y_{DISP} + p_L L - p_C\gamma_C - p_L\gamma_L} \tag{30}$$

By calibrating $\frac{stp}{rr}$ we have fixed the value of β_L. The value of β_C is defined by $\beta_C = 1 - \beta_L$.

Second, we turn the calibration of the minimum levels of consumption and leisure γ_C **and** γ_L. As mentioned above, the value of γ_C is fixed by the assumption $\frac{p_C\gamma_C}{y_{TR}} = 0,2$. We can rewrite the optimal leisure demand, given by expression (4), as

$$p_L\gamma_L = \frac{p_L L - \beta_L \frac{stp}{rr}(y_{DISP} + p_L L - p_C\gamma_C)}{1 - \beta_L \frac{stp}{rr}}, \tag{31}$$

where $\beta_L \frac{stp}{rr}$ is determined by expression (29) above, $\beta_L \frac{stp}{rr} = \frac{\epsilon_{LS} p_L L_S}{y_{TR} - p_C\gamma_C}$. Expression (31) defines the minimum level of leisure γ_L.

Third, we derive the expressions for δ_K **and** δ_{LEM}. We start by rewriting the constraint 6 in the profit maximisation problem, such that

$$X_D^{\frac{\sigma_1-1}{\sigma_1}} = \delta_K^{\frac{1}{\sigma_1}} K^{\frac{\sigma_1-1}{\sigma_1}} + \delta_{LEM}^{\frac{1}{\sigma_1}} LEM^{\frac{\sigma_1-1}{\sigma_1}}$$

Using the zero profit condition, we can write

$$\frac{p_K K + p_{LEM} LEM}{p_D} X_D^{-\frac{1}{\sigma_1}} = \delta_K^{\frac{1}{\sigma_1}} K^{\frac{\sigma_1-1}{\sigma_1}} + \delta_{LEM}^{\frac{1}{\sigma_1}} LEM^{\frac{\sigma_1-1}{\sigma_1}}$$

Restructuring terms, we get

$$\underbrace{X_D^{-\frac{1}{\sigma_1}} \frac{p_K}{p_D} K}_{(1)} + \underbrace{X_D^{-\frac{1}{\sigma_1}} \frac{p_{LEM}}{p_D} LEM}_{(2)} = \underbrace{\delta_K^{\frac{1}{\sigma_1}} K^{\frac{\sigma_1-1}{\sigma_1}}}_{(3)} + \underbrace{\delta_{LEM}^{\frac{1}{\sigma_1}} LEM^{\frac{\sigma_1-1}{\sigma_1}}}_{(4)}$$

Setting (1) = (3) and (2) = (4) gives us a possible solution for δ_K and δ_{LEM}:

$$\begin{aligned} \delta_K &= \left(\frac{p_K}{p_D}\right)^{\sigma_1} \frac{K}{X_D} = \left(\frac{p_K K}{p_D X_D}\right)^{\sigma_1} \left(\frac{K}{X_D}\right)^{1-\sigma_1} \\ \delta_{LEM} &= \left(\frac{p_{LEM}}{p_D}\right)^{\sigma_1} \frac{LEM}{X_D} = \left(\frac{p_{LEM} LEM}{p_D X_D}\right)^{\sigma_1} \left(\frac{LEM}{X_D}\right)^{1-\sigma_1} \end{aligned}$$

The substitution elasticity σ_1 is fixed exogenously. Therefore, we can obtain the scale parameters δ_K and δ_{LEM} by using observed value shares and volumes.

This direct tax rate on households τ_{DT} is simply determined by dividing the total amount of direct taxes paid by households (from government accounts) by the total income, which includes factor income plus transfers received minus transfers paid (from household accounts).

The labour productivity parameter is calibrated as $\zeta = \frac{p_L L_D}{L_D}$. The numerator is the demand for labour services and equals the input of labour from input-output tables. The denominator is the demand for labour in hours, calculated by multiplying the number of employed people (from employment data) with 1700 hours, which we assume is the equivalent of a yearly full time equivalent.

Prices are calibrated by dividing data in value by data in volume. We assume $p_W = 1$ and $p_{EXP} = 1$. Prices $p_Y = 1$ for sectors without import duties. Prices $p_Y > 1$ for sector with import duties (branches 1 and 7-12).

Table 11 below shows the data sources used and where we obtained them.

Data	***Source***
Input-Output tables	Federal Planning Bureau
Government accounts	Federal Planning Bureau
Household accounts	Federal Planning Bureau
Consumption matrix	GEM-E3 Europe, Eurostat
Investment matrix	GEM-E3 Europe, Eurostat
Employment data	Federal Planning Bureau
Energy balances	Brussels: IBGE / BIM
	Flanders: VITO
	Wallonia: ICEDD
Emissions	Federal Planning Bureau
Energy prices and tax rates	International Energy Agency
Trade data	Federal Planning Bureau

Table 11: Data sources

The values for the conversion factor θ_F are shown in table 12. For completeness we show the values for all energy sectors.

		Brussels	***Flanders***	***Wallonia***
2	Coal	0.341	0.365	0.347
3	Oil	0.082	0.155	0.091
4	Gas	0.252	0.259	0.260
5	Electricity	0.074	0.071	0.074

Table 12: Conversion factor θ_F in PJ

The uncompensated own price elasticities implied by the calibration of households' preferences are shown in tabel 13. For non-linked non-durables, they are caculated as $(1-\beta_{ND})\frac{\gamma_{ND}}{C_{ND}}-1$. The elasticities shown for linked non-durables take the stock of durables as given. For durables, we show the price elasticity of the optimal stock of durables with respect to the price of durables p_{DG}.

	Own price elasticities	*Brussels*	*Flanders*	*Wallonia*
1	Food, Beverages and Tobacco	-0.32	-0.34	-0.34
2	Clothing and Footwear	-0.18	-0.19	-0.19
3	Housing and Water expenses	-0.41	-0.41	-0.40
4	Fuels and Power	0.21	0.21	0.21
5	Housing Furniture and Operation	-0.12	-0.13	-0.13
6	Heating and Cooking Appliances	-0.18	-0.18	-0.18
7	Medical Care and Health Expenses	-0.22	-0.22	-0.22
8	Transport Equipment	-0.10	-0.10	-0.10
9	Operation of Transport Equipment	0.21	0.21	0.21
10	Purchased Transport	-0.30	-0.29	-0.29
11	Telecommunication services	-0.29	-0.30	-0.30
12	Recreation, Entertainment, Culture, etc.	-0.50	-0.50	-0.49
13	Other Services	-0.48	-0.49	-0.49

Table 13: Marshellian own price elasticities

The structure of the SAM can be illustrated by table 14, which presents quadrant.1, 2 and 3 of the SAM of Flanders. The first quadrant (upper left) shows intermediate demand. Not all sectors are shown. Row totals equal column totals in the first quadrant. Remark that there is no direct use of coal (branch 2) in the agriculture sector (branch 1). The second quadrant (upper right) shows final demands of households C, government G, the rest of the world EXP and gross fixed capital formation $GFCF$. The third quadrant (lower left) displays imports Z, taxes, subsidies and factor inputs. Note that row totals over the first two quadrants equal column totals across quadrants 1 and 3.

Flanders	*Industry branches*			*Final demand*				
Million €	*01*	...	*18*	C	*G*	*GFCF*	EXP	***Row total***
01	299.0		108.0	1591.9		82.9	2198.7	9954.5
02			2.1	19.6			80.5	
03	202.9		398.4	1888.1	0.2	25.3	7086.8	
04	1.6		65.0	1219.1			353.9	
05	108.5		547.9	1563.2		28.9	1196.2	
06	11.6		113.1	302.8	0.8	1381.3	11888.2	
07	318.9		1707.9	1010.8	916.3	242.6	27084.5	
08	4.3		139.5	552.9	0.8	51.1	8107.3	
09	191.3	...	299.6	1743.8	52.4	9559.5	19882.2	...
10	10.0		51.5	4601.5	0.3	3447.9	25855.4	
11	15.9		594.6	2614.5	3.1	1161.2	13718.1	
12	1127.4		690.5	13296.7	5.1	201.9	22116.5	
13	4.8		632.4	275.6	0.7	15349.1	3284.5	
14	11.4		264.2	1335.3	532.2	206.4	3068.7	
15	0.8		49.2	154.7	0.0	10.4	2814.2	
16	175.8		696.1	5671.0		54.7	2444.3	
17	680.8		5078.4	41403.3	2788.5	7470.3	31855.2	
18	209.8		3352.2	12099.1	34379.6	312.5	1313.8	55252.5
Imports Z	4437.1		9006.2					
T_{VAT}	21.2		1613.6					
T_{SUB}	-273.6	...	-2240.3					
T_{DUT}	62.9							
T_{IT}	53.8		515.6					
T_{EN}			61.3					
Labour	407.7	...	25596.9					
Capital	1870.6		5908.7					
Column total	9954.5	...	55252.5					

Table 14: Quadrants 1, 2 and 3 of the Social Accounting Matrix for Flanders, 2005

As a final remark, we point out that coal mining is no longer operative in Belgium since 1992. Therefore, inputs in the coal sector (branch 2) consist of only imports.

J Energy and environment

As explained in a previous section, the excise tax is tax per volume. Note that we take into account that agriculture and water and air transport are largely exempted from excise taxes. Let us first look at the calibration of the energy taxes on firms τ_{EN}. Multiplying the tax rates per fuel from the International Energy Agency (IEA) with the fuel use per sector from regional energy balance sheets, we get the total energy taxes paid by sector. Dividing this by the intermediate demand for fuels in the input-output table, we obtain a tax per volume. Next, we use this tax to calculate the price of oil p_{oil} including indirect and energy taxes. By rewriting the equation for p_{oil} (see section H) we obtain the tax per PJ:

$$\tau_{EN} = \frac{p_{oil,t} - (1 + \tau_{it})p_{Y,t}}{\varphi_F \theta_F}$$

A similar procedure applies for the energy taxes on linked non-durable consumption of households τ_{en}. The total of oil excises paid by households are allocated over heating and transportation based on information from energy balance sheets.

The parameter φ_F, the share of energy use of a fuel, is included because excises do not apply on non-energetic use of oil. The calculation of the share of energy use φ_F is based on energy balance sheets, which typically distinguish between energetic and non-energetic final industrial use of fuels. Table 15 below shows the values of parameter φ_F by sector.

	Branches	***Brussels***	***Flanders***	***Wallonia***
1	Agriculture	0.988	0.994	0.993
2	Coal	1	1	1
3	Crude oil and refined oil products	0.05	0.038	0.05
4	Natural gas	1	1	1
5	Electric Power	1	1	1
6	Ferrous and non-ferrous ore and metals	0.989	0.979	0.998
7	Chemical products	0.989	0.056	0.821
8	Other energy intensive industries	0.988	0.977	0.988
9	Electrical goods	0.989	0.977	0.99
10	Transport equipment	0.989	0.977	0.99
11	Other equipment goods	0.98	0.98	0.98
12	Consumer goods industries	0.989	0.98	0.987
13	Building and construction	0.832	0.81	0.815
14	Land Transport	0.916	0.789	0.898
15	Other Transport	0.99	0.961	0.965
16	Credit and insurance	1	1	1
17	Other market services	0.973	0.896	0.954
18	Non-market services	1	1	1

Table 15: Share of energy use of oil φ_F by sector and region

Remark that non-energy use of oil is especially relevant in the chemical sector in Flanders. Due to the heterogeneity of the activities in the chemical industry, the non-energy share is less important in Wallonia and Brussels (the latter hosts mainly headquarters). A similar parameter for energetic use of fuels exists for households (φ_{HH}). This way, we take into account the fact that no excises are paid on, for instance, motor oil as an engine lubricant.

Furthermore, a conversion factor θ_F was included in the fuel price to transform the energy tax per petajoule to a tax per volume (the unit of θ_F is PJ). The factor θ_F (shown in table 12) is obtained by dividing p_Y by an energy price (€/PJ) based on energy price statistics of the IEA. The same is done for households.

The CO_2 emissions of firms are calculated by multiplying the deliveries of coal, oil and gas sectors to the other industry branches with the shares of energy consumption (by fuel type and industry; similar to φ_F) and the emission coefficients. These emission factors are based on energy use by sector as detailed in the energy balance sheets and the coefficients in table 16, which are the default values from IPCC (2006):

Source	***kton/PJ***
Coal	95
Coke	107
Oil	73
Natural Gas	56
Coke Gas	44
Blast Furnace Gas	260

Table 16: Emission coefficients

For households, a similar procudure applies: the consumption of non-durables that is linked to the use of durables, multiplied with the share of energy use and the emission coefficients, gives rise to the carbon emissions.

K More results

		Federal gov.		*Regional gov.*	
		Lump sum	***Labour tax***	***Lump sum***	***Labour tax***
1	Food, Beverages and Tobacco	0.02	0.01	0.02	0.01
2	Clothing and Footwear	0.03	0.01	0.02	0.01
3	Housing and Water expenses	0.02	0.00	0.02	0.00
4	Fuels and Power	0.06	0.05	0.06	0.05
5	Housing Furniture and Operation	0.02	0.00	0.02	0.01
6	Heating and Cooking Appliances	0.05	0.04	0.05	0.04
7	Medical Care and Health Expenses	0.04	0.00	0.03	0.01
8	Transport Equipment	0.27	0.25	0.27	0.26
9	Operation of Transport Equipment	1.14	1.13	1.14	1.13
10	Purchased Transport	0.10	0.07	0.04	0.04
11	Telecommunication services	0.02	0.00	0.02	0.00
12	Recreation, Entertainment, Culture, etc.	0.03	0.01	0.02	0.01
13	Other Services	0.03	0.00	0.02	0.01

Table 17: Consumption price changes (Flanders): % difference with baseline in 2050

		Federal government reform						Regional government reform					
		Lump sum			***Labour taxes***			***Lump sum***			***Labour taxes***		
		Br	***Fl***	***Wa***	***Br***	***Fl***	***Wa***	***Br***	***Fl***	***Wa***	***Br***	***Fl***	***Wa***
01	Agriculture	-0.07	-0.02	-0.01	0.04	0.01	0.01	-0.06	-0.01	-0.01	-0.11	0.01	-0.01
03	Crude oil and refined oil products	-0.17	-0.01	-0.02	-0.14	-0.01	0.01	-0.08	-0.01	-0.02	-0.22	0.03	-0.06
04	Natural gas	0.02	0.01	0.01	0.03	0.03	0.03	0.01	0.00	0.00	-0.01	0.05	-0.03
05	Electric Power	-0.03	-0.04	-0.04	-0.02	-0.02	-0.02	-0.01	-0.03	-0.01	-0.02	0.02	-0.04
06	Ferrous and non-ferrous ore and metals	-0.66	0.10	0.01	-0.40	0.11	-0.04	-0.02	-0.18	0.24	-0.39	0.18	-0.14
07	Chemical products	-0.18	-0.02	-0.10	0.23	-0.02	-0.09	0.52	-0.10	0.01	-1.07	0.09	-0.01
08	Other energy intensive industries	-0.54	-0.15	-0.09	-0.47	-0.11	-0.06	0.49	-0.40	0.24	0.27	-0.25	0.13
09	Electrical goods	-0.04	0.02	-0.30	0.04	0.04	-0.22	0.02	-0.07	0.02	-0.24	0.09	-0.24
10	Transport equipment	0.00	-0.03	-0.47	0.03	-0.01	-0.22	0.05	-0.04	-0.10	-0.28	0.07	-0.48
11	Other equipment goods	-0.04	-0.03	-0.10	0.01	0.00	-0.06	-0.01	-0.04	-0.01	-0.12	0.03	-0.11
12	Consumer goods industries	0.03	0.00	-0.33	0.07	0.04	-0.29	0.15	-0.07	0.07	-0.03	0.00	-0.04
13	Building and construction	-0.02	-0.02	-0.04	0.01	0.00	-0.02	-0.01	-0.03	-0.01	-0.09	0.04	-0.07
14	Land Transport	0.69	0.02	-1.75	0.91	-0.05	-1.74	0.91	-1.41	1.24	0.37	-0.76	0.78
15	Other Transport	0.01	-0.05	-0.01	0.01	-0.01	0.03	0.00	-0.05	-0.02	-0.04	0.01	-0.10
16	Credit and insurance	-0.01	-0.01	-0.02	0.02	0.02	0.01	-0.02	-0.01	-0.01	-0.04	0.09	-0.03
17	Other market services	-0.02	-0.03	-0.03	0.02	0.00	-0.01	-0.01	-0.03	-0.01	-0.05	0.02	-0.03
18	Non-market services	0.06	0.02	-0.05	0.08	0.03	-0.03	0.03	-0.02	0.02	-0.31	0.31	-0.24

Table 18: Production level: % difference with baseline in 2050