SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

SPSD II

GREENMOD II: DYNAMIC REGIONAL AND GLOBAL MULTI-SECTORAL MODELLING OF THE BELGIAN ECONOMY FOR IMPACT, SCENARIO AND EQUITY ANALYSIS

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SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 1:
Sustainable production and consumption patterns

FINAL REPORT

Dynamic Regional and Global Multi-Sectoral Modelling of the Belgian Economy for Impact, Scenario and Equity Analysis
GreenMod II

CP/51

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May 2006

BELGIAN SCIENCE POLICY ULB UCL ECONOTEC CONSULTANTS

BELGIAN SCIENCE POLICY

D/2007/1191/46
Published in 2007 by the Belgian Science Policy
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Wetenschapsstraat 8
B-1000 Brussels
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1. Project title

GreenMod II: Dynamic Regional and Global Multi-Sectoral Modelling of the Belgian Economy for Impact, Scenario and Equity Analysis

2. Introduction

2.1. Context and summary

Since the ratification of the Kyoto Protocol by the European Union and the "Burden Sharing Agreement" between the EU Member States, several environmental policy measures have been considered and widely debated in Belgium and in other countries. Under the "Burden Sharing Agreement", Belgium committed herself to reduce her greenhouse gas emissions by 7.5 percent by 2008-2012 compared to their 1990 levels. Achieving this target may have very different impacts on the three Belgian regions (Brussels, Flanders and Wallonia), on the different sectors and households. It is therefore important to examine the economic and environmental impacts of implementing the Kyoto Protocol on the three Belgian regions at a very detailed level.

Currently, the only existing tool in Belgium capable of providing regional and sectoral impacts of domestic and international energy and environmental policies is the model GreenMod whose first version has been developed by our team thanks to the funding from the PPS Science Policy (program SPSD II).

In this second phase, a new version of GreenMod has being developed. GreenMod II now includes a recursively dynamic version of GreenMod with imperfect competition, increasing returns to scale, vintage capital, backstop technologies, wage bargaining, search and matching labour market model, labour adjustment costs and a very detailed disaggregation level. The database of the model has also been completely updated.

The new version of the model is used to evaluate the economic policies currently considered in the energy or climate field, fiscal and non-fiscal (voluntary agreements, rational use of energy etc.) measures. GreenMod II is intended to act as an analytical and quantitative support for decision-making in the energy and environment field, in particular for the policies to reduce greenhouse gas emissions.

The first year of the project was devoted to data collection, in order to update the sectoral and regional database for Belgium to the reference year 2003, the construction of a simplified version of GreenMod II and its implementation in the software GAMS, the development of a microsimulation model (linked with GreenMod II), the preliminary estimation of the elasticities of substitution between capital and energy corresponding to five manufacturing sectors in GreenMod II, and finally the implementation of the tradable pollution permits in a dynamic framework. In the second year of the project, GreenMod II has been fully tested and finalised, and has been used for policy analysis.

2.2. Objectives

The main objective of this project is to develop a new version of GreenMod, and to update and improve its database and its parameterisation. GreenMod II is destined to become a lasting, flexible tool to contribute to the energy and environmental policy assessment and to act as a support for decision-making in energy and environmental matters, notably in the policies of pollution abatement. GreenMod II takes into consideration all interdependencies at the level of the three regions (Brussels, Flanders and Wallonia) in order to study the impacts related to economic measures in the energy and environment field. The model also allows us to examine the differentiated impacts of economic measures on different socio-economic groups. GreenMod II is a recursively dynamic version of GreenMod with imperfect competition, increasing returns to scale, and a very detailed disaggregation level (62 sectors, 69 commodities, about 10 socio-economic groups). This version is very important as the economic structure of the three regions is very different. It is therefore important to take the industrial organisational differences into account as the literature shows that these differences are often crucially important on the outcome of economic policies.

GreenMod II is intended to act as an analytical and quantitative support for decision-making in the energy and environment field, in particular for the policies to reduce greenhouse gas emissions. GreenMod II also aims at filling the gaps left by the other models currently used in Belgium, in particular by explicit bottom-up modelling of the three Belgian regions (Brussels, Flanders, Wallonia), by further disaggregating the production and consumption blocs (62 sectors, 69 commodities), by distinguishing different types of households to study the distributional effects of environmental policies, and finally by introducing tradable permits along with other fiscal and non-fiscal economic policy instruments.

The project also explores the main challenges related to energy and climate policies in the socioeconomic, energetic and environmental fields and especially analysis of the impacts of policies and measures related to the climate field. In addition to the construction of the model as a lasting and practical tool to help decision makers, the research project aims at exploring the main issues inherent to energy and environmental policies.

Four avenues are put forward: (i) the analysis of the impacts of the policies and measures considered in the climate field (fiscal, non-fiscal, voluntary agreements etc.), (ii) the analysis of different burden sharing schemes between the three Belgian regions, (iii) the distributional impacts of various scenarios on different socio-economic groups in the three regions, (iv) and finally, the links and the interactions between the Belgian federal and regional policies and markets.

3. Detailed description of the scientific methodology

The core framework of the new version of the model GreenMod II is based on the general equilibrium approach, but it is extended further to include imperfect competition, wage bargaining, search and matching model of regional labour markets, dynamics and disequilibrium on some markets.

GreenMod II combines general equilibrium with game theory to represent differences in the industrial structure of Belgian regions. A high level of detail is indispensable to show and evaluate the structural adjustment generated by the pollution abatement policies. The sectoral (62 sectors and 69 commodities for each region of the model) and the regional (Brussels, Flanders and Wallonia) disaggregation are therefore crucial. The regional dimension is of great value given that each region in Belgium has its own structural features and needs specific policies. The representation of location, entry and exit decisions of the firms through the spatial oligopoly theory is equally important because differences in the abatement strategies among the regions lead to relocation of firms, changes in market concentration and geographical distribution of production and consumption of energy-intensive products.

Technical change is well known to have a strong influence on projections of greenhouse gas emissions and the costs of their control. Therefore, technical change is represented in GreenMod II through three types of backstop technologies: a hydrocarbon-intensive technology for natural gas (coal gasification), a carbon-free electric power generation based on biomass and a carbon-free electric power generation based on wind power.

Labour market in GreenMod II is represented using the search and matching model of Pissaridies (2000). The process of wage formation in each sector and region is described by the bargaining mechanism between the firms and the trade unions (Gilles et al, 2003). Furthermore, labour adjustments costs associated with searching for new workers are paid by the firms.

The targets established by the Kyoto Protocol for the emissions reduction require an important change in the structure of consumption and production in the short-run. However, the use of a less carbon-intensive input mix in the production process requires large replacement or retrofit rates for the capital stock. Therefore, special attention has been paid to modelling of capital structure and its evolution over time in GreenMod II. Two types of capital are distinguished in each period: a "malleable" part and a "rigid" part (Jacoby et al., 2004), whereas the possibilities of substitution among factors of production are assumed to be higher for the malleable than for the rigid capital (vintage capital). Thus, the technology is assumed to have a putty/semi-putty specification (Van der Mensbrugghe, 1994).

In order to address the social equity issues between different socio-economic groups, GreenMod II is linked with a microsimulation model developed by our team which enables to evaluate the distributional effects of various environmental scenarios on individual members of the households in the three Belgian regions.

GreenMod II compares the effects of alternative economic policies in terms of a large number of sectoral and national variables such as sectoral output, employment, investment, and welfare. It evaluates the impacts on the greenhouse gases (CO2, CH4 and N2O). GreenMod II describes the challenges in terms of budget for every agent, including the federal and regional public administrations.

The project includes the following stages and features:

3.1. Construction of the database

GreenMod II is designed to measure the direct, indirect and induced economic and environmental impacts of policy changes on the economy in the short, medium and long run. The input-output core enables the model to trace the extent and the channels of changes in policy and international environment. During the second year of the project, the main task consisted of updating the regional social accounting matrices (SAM) for 1997 to the year 2003. Moreover the new database i.e. the SAM 2003 is more disaggregated in terms of taxation. The new rules of transfers from the federal government to the regions and communities are also taken in account. The SAM 2003 also takes into account households characteristics in terms of commuting. New sources of data were used to improve the quality of the database and thus the model results. This task was extremely challenging, given that there are no official regional input-output tables or social accounting matrices in Belgium, regional data is still scarce in many respects and data often requires adjustments and consultations with the experts.

The main elements used for the construction of the new database were the SAM for 1997, the supply and use tables for 2001, provided by the Belgian National Bank, data on energy consumption by branch of activity and by region provided by Econotec and other data listed here below. We have collected highly detailed raw data at the national and regional level on national accounts, regional accounts, input-output table, data by branch of activity (production, value added, employment, etc), public finance, household surveys, labour force surveys, data on energy use and pollution, trade data, industrial concentration index by branch of activity, etc. We have also obtained confidential regional data on household budget, as well as on production, investments, number of employees by qualification, work hours, wages, etc. from the National Institute of Statistics (NIS). We have further received from the NIS, data on migration between regions, data on workers by region, by profession, by residence place and by work place. The new SAM is more disaggregated than the SAM 1997, especially with regard to the energy sectors. All this processes led to the creation of a 62 sectors, 69 commodities Social Accounting Matrix for Belgium.

After the data collection, we regionalized the matrix, by using regional data when available, or by using other regional data as targets. In order to achieve this tremendous task, the following regional data were used:

- statistics on production PRODCOM (NIS)
- the supply and use tables (NBB)
- statistics on national employment (Ministry of Employment)
- statistics on regional employment by occupation (NBB)
- statistics on turnover from the VAT report (NIS)
- statistics on value added (NBB)
- regional turnover of firms (NIS)
- investments by region (NIS)
- population by region (NBB)
- households Budget Survey (NIS)
- remuneration of employees by region (NBB)
- the household income tax (HIT) by region (Ministry of Finance)
- the value-added tax (VAT) by region (Ministry of Finance)
- the excise duties (Ministry of Finance and NBB)
- the regional taxes (NBB)
- debt by region (Ministry of Finance)
- industrial concentration indexes (NIS)
- production by region (NBB and own estimates).

This led to the regionalization of the Belgian social accounting matrix into three linked matrices for Flanders, Brussels, and Wallonia with the integration of all the national-regional public finance data in the regional SAM. The new fiscal system and the new structure of transfers are explicitly taken in account.

3.2. Construction of the new version of the model GreenMod II

3.2.1. Model description

GreenMod II incorporates the economic behaviour of five groups of economic agents in each Belgian region: firms, trade unions, households, government and the rest of the world. All economic agents are assumed to adopt an optimizing behaviour under relevant budget constraints.

Sixty-two types of activity sectors are distinguished, consisting of both public and private enterprises[1]. Each sector produces one type or several types of commodities. Also, different sectors can produce the same type of commodity. For example, manufacture of coke and refined petroleum products produces nine different types of commodities: coke oven coke, petroleum coke, nuclear energy, gasoline, heavy oil, gas oil, coke oven gas, refinery gas and other combustible, while non-nuclear and nuclear electricity sectors produce one homogenous good: electricity. In total, GreenMod II accounts for sixty-nine types of commodities, out of which ten types of energy inputs.

GreenMod II explains the differences in the industry structure between the regions by variation in the economies of scale. This is a usual simplifying assumption made in general equilibrium models (Harris, 1984; Willenbockel, 1994). Strategic interactions between firms in an imperfectly competitive industry are represented either using spatial Cournot oligopoly or monopolistic competition frameworks with free entry and exit. These frameworks have recently been used in general equilibrium literature to model firms' location and different industry structures for studying energy related issues (Babiker, 2005).

GreenMod II incorporates the representation of a range of oligopolistic and monopolistically-competitive sectors. These sectors differ in their regional location, the number of operating firms and the degree of the economies of scale, which they enjoy. Each individual firm is a profit-maximiser. It chooses its output level based upon its marginal costs and the price elasticities of demand that it faces. The behaviour of individual firms defines the overall performance of the industry in terms of number of operating firms, output and price levels. Performance of an industry is represented using Cournot-Nash equilibrium. All oligopolistic and monopolistically-competitive firms in GreenMod II enjoy their market power at the country level. They exercise their market power over the three Belgian regions and cannot price differentiate between them. They take into account the weighted perceived elasticities of demand of the three Belgian regional markets while choosing their outputs and prices.

GreenMod II incorporates the representation of wage bargaining between the trade unions and firms. The bargaining process determines the wage levels in different sectors and regions. The outcome of the bargaining process depends upon the optimization functions of the two participating agents: firms and trade unions. Trade unions maximize their utility function that depends upon the total wage of their members which are employed and total unemployment benefits of unemployed ones. Firms on the other hand try to maximize their profits. As a result,

[1] A presentation of the production sectors considered in the model is given in section 6.1.

total profits of the firms are shared between the firms and the workers, in a proportion depending upon the trade unions bargaining power.

The functioning of the labour market in GreenMod II follows the search and matching model of Pissaridies (2000). In each period of time firms post a certain number of vacancies on the labour market, depending on the required level of employment. The firms pay a certain unit cost per each posted vacancy. Unemployed people search for jobs. However, not every search-job match is successful because of the individual qualities of the workers. Successful matches, leading to further employment, are formed according to the matching function from vacancies and unemployed people. The matching function in GreenMod II has a Cobb-Douglas functional form.

Households are split into deciles to allow analyzing the income distribution effects of different policy measures. Government behaviour is modelled at three different levels: federal, regional, and community (French community). Both federal and regional tax systems are modelled in a detailed way. With regard to the rest of the world the economy is treated as a small open economy with no influence on world market prices.

The model has a recursive dynamic structure composed of a sequence of several temporary equilibria, in which current savings determine future capital accumulation and the growth rate of the economy. It is assumed that in the steady state the number of oligopolistic firms does not change and that output of each firm increases with the same rate as the rest of the regional economy. The simulation horizon of the model is set at 25 years but can be extended in a flexible way. The model is solved dynamically with annual steps.

The targets established by the Kyoto Protocol for the emissions reduction require an important change in the structure of consumption and production in the short-run. However, the use of a less carbon-intensive input mix in the production process requires large replacement or retrofit rates for the capital stock. Therefore, special attention has been paid to modelling of capital structure and its evolution over time in GreenMod II. Two types of capital are distinguished in each period: a "malleable" part and a "rigid" part (Jacoby et al., 2004), whereas the possibilities of substitution among factors of production are assumed to be higher for the malleable than for the rigid capital (vintage capital). Thus, the technology is assumed to have a putty/semi-putty specification (Van der Mensbrugghe, 1994).

Technical change is represented in the model by three types of backstop technologies: a carbon-free electric power generation based on biomass, a carbon-free electric power generation based on wind power and a hydrocarbon-intensive technology for natural gas (coal gasification).

GreenMod II is calibrated on a highly disaggregated regional Social Accounting Matrix for Belgium, which comprises besides the complex government structure, ten types of households, 62 production sectors and 69 types of commodities.

The following conventions are adopted for the presentation of the model. Variable names are given in capital letters while small letters denote parameters calibrated from the database (SAM) and elasticity parameters.

3.2.2. Firms

The CGE model does not take into account the behaviour of individual firms, but of groups of similar ones aggregated into sectors. The model distinguishes sixty-two production sectors (summarized in section 6.1) for each region. Four of them – manufacture of coke, refined petroleum products and nuclear fuel; production and distribution of natural gas; production and distribution of nuclear electricity; production and distribution of non-nuclear electricity –

concern the supply and distribution of conventional energy[2]. The remaining sectors concern the production of other goods and services.

Gross output for each sector and each region is determined from a nested production structure. The nesting of the production structure is differentiated between sectors according to the specific production technologies used by the sectors. Three main ways of nesting the production structure are distinguished in the model.

The first group of production sectors *(LEO)* with the same nesting structure includes: other mining and quarrying; manufacture of coke, refined petroleum products and nuclear fuel; production and distribution of natural gas; production and distribution of nuclear electricity and collection, purification and distribution of water. At the outer nest producers are assumed to choose intermediate inputs of non-energy goods, energy inputs and a capital-labour *(KL)* bundle, according to a Leontief production function, which assumes an optimal allocation of inputs. The Leontief structure is dictated by the technological process, i.e. there are no substitution possibilities between crude oil and other non-energy goods consumed in the production process by the manufacture of coke and refined petroleum products.

Consumption of energy inputs is differentiated among sectors and is dictated by the structure of the database. For instance, manufacture of coke, refined petroleum products and nuclear fuel uses coal, petroleum coke, gasoline, heavy oil, gas oil, refinery gas, natural gas and electricity in the production process, while production and distribution of non-nuclear electricity consumes coal, gasoline, heavy oil, gas oil, coke oven gas, natural gas and electricity as intermediate energy inputs. Furthermore, consumption of energy inputs is also differentiated among sectors acting in different regions to account for the specific production technologies in use. Overall, ten types of energy inputs are distinguished, that can be consumed in the production process: coal, petroleum coke, gasoline, heavy oil, gas oil, coke oven gas, refinery gas, other combustibles, natural gas and electricity. Crude petroleum is not treated as energy input in this context.

At the second nest, producers choose the optimal level of labour and capital, according to a constant elasticity of substitution (CES) function. Thus, the demand for capital and labour depends on the substitution possibilities between the two factors of production and their relative prices.

Prior to the moment when the backstop technologies for natural gas and electricity become competitive energy sources, demand for the two energy inputs (natural gas and electricity) is only given by their conventional fuels counterparts. When the backstops for the two energy sources become competitive energy sources, backstop natural gas and electricity are assumed to be perfect substitutes for their conventional counterparts. The nested structure and the functional forms used by these sectors are given in Fig. 3.1.

[2] There is no domestic production of coal and lignite, natural gas, crude petroleum and uranium and metal ores. However, these commodities are imported from the rest of the world and traded between the Belgian regions.

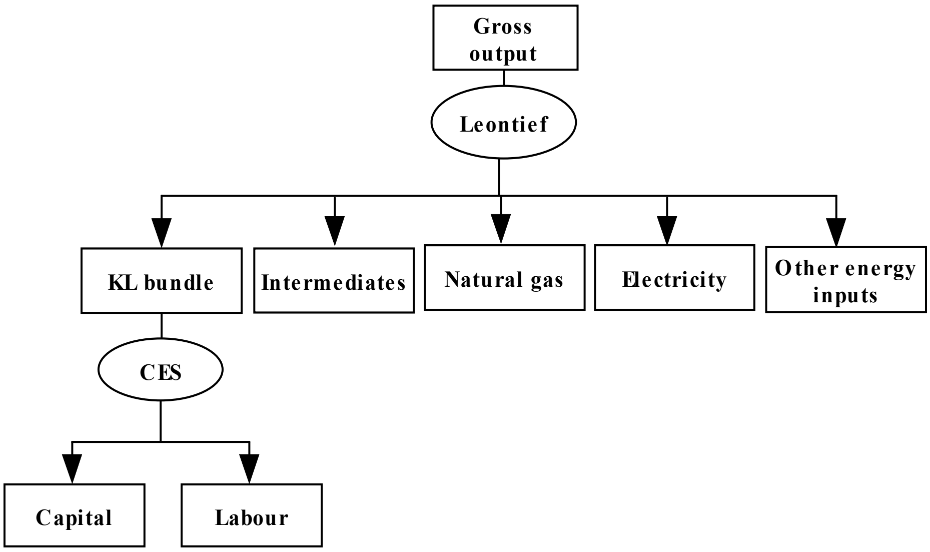

Fig. 3.1. A nested Leontief and CES production technology for the first group of production sectors *(LEO)*

The second group of production sectors *(CES)* with the same nesting structure includes all the other industrial and services sectors in the model which are not included in the first *(LEO)* group. Gross output in this case is also determined from a nested production structure. At the outer nest producers are assumed to choose intermediate inputs of non-energy goods and a capital-labour-energy *(KLE)* bundle, according to a Leontief production function. At the second stage, producers choose the optimal level of labour input and capital-energy *(KE)* composite. Production substitution possibilities are reflected in this case by a constant elasticity of substitution (CES) function. The optimal level of capital and energy is determined at the third stage, according to a CES function. Further, at the fourth stage, producers allocate the energy bundle between electricity and non-electric energy commodities. Production substitution possibilities are again reflected by a CES function. The allocation between different non-electric energy commodities: coal, petroleum coke, gasoline, heavy oil, gas oil, coke oven gas, refinery gas, other combustibles and natural gas is given at the fifth nest by another CES function. Thus, substitution elasticities between electricity and other fuels or between non-electric energy inputs to which abatement costs are rather sensitive can be set in a flexible way.

When backstops technologies become competitive energy sources, backstop electricity is assumed to be a perfect substitute for its conventional counterpart, while backstop natural gas is a perfect substitute for the conventional natural gas. Prior to this moment, demand for electricity and natural gas is only given by their conventional counterparts.

The complex nested structure and the functional forms used in the second group of production sectors are summarized in Fig. 3.2.

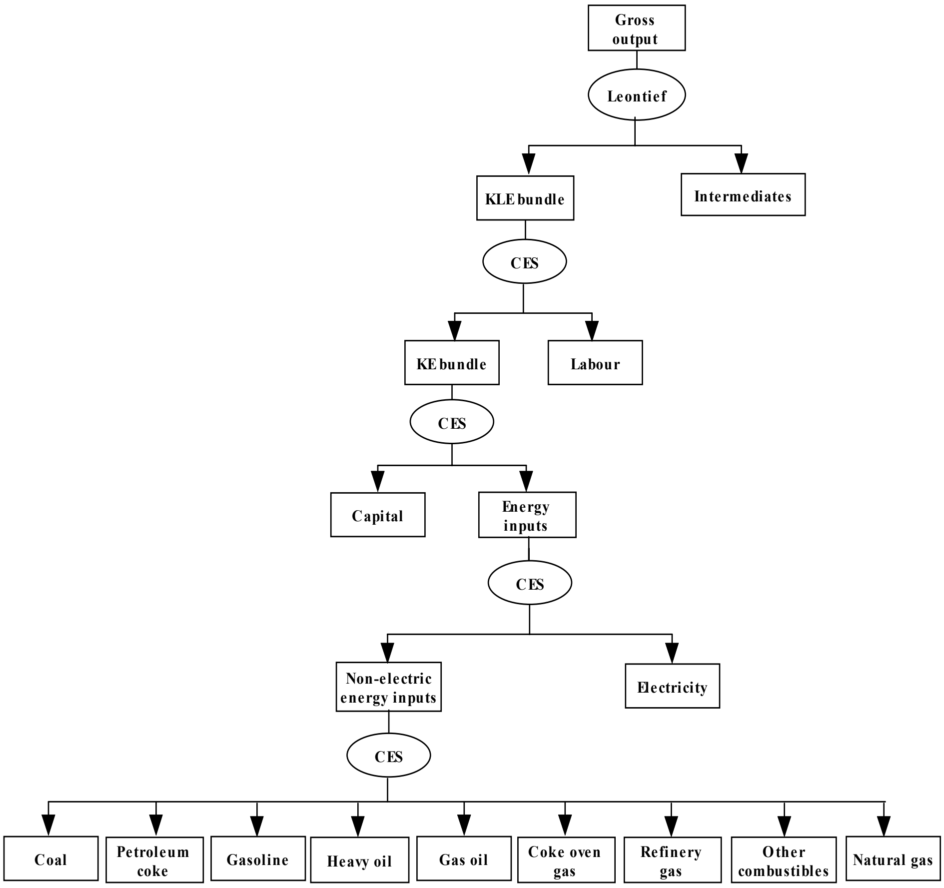

Fig. 3.2. The nested CES and Leontief production technology for the second group of production sectors (CES)

The third group of production sectors *(AGR)* with regard to the nesting structure includes: agricultural sector, hunting and related service activities; forestry, logging and related service activities; fishing, operation of fish hatcheries and fish farms. The nesting structure of this group is similar to the second one *(CES)* but it accounts for an additional factor of production: natural resources. The structure of production together with the corresponding functional forms is provided in Fig. 3.3.

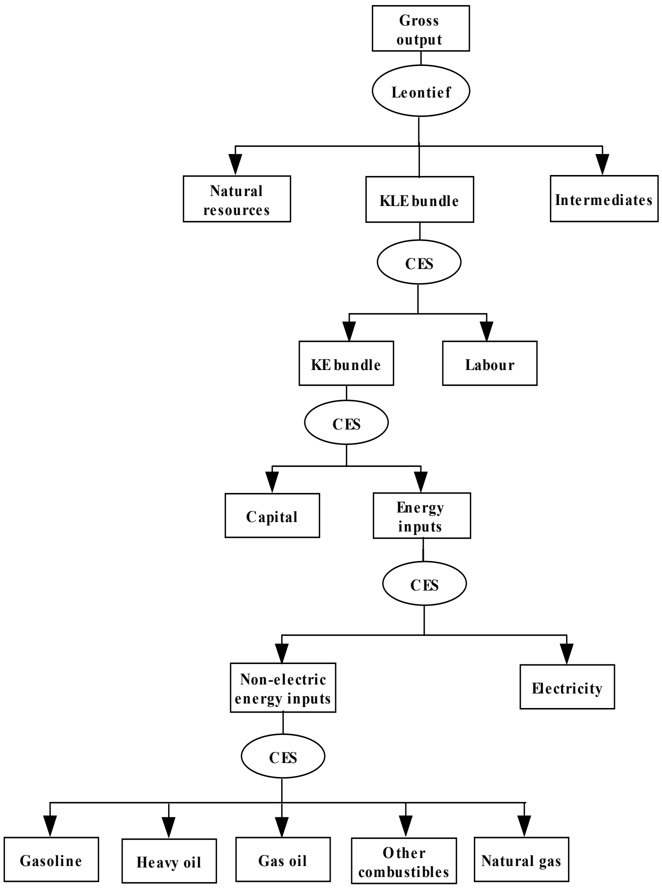

Fig. 3.3. A nested CES and Leontief production technology for the third group of production sectors (AGR)

For fifteen of the production sectors belonging to the *LEO, CES* and *AGR* groups, summarized in Table 3.1[3], we use the assumption that producers operate on monopolistically-competitive markets and maximize profits (or minimize costs) to determine optimal levels of inputs and output. For the rest of the production sectors from the *LEO, CES* and *AGR* groups (see Table 3.1) we have chosen to use Cournot competition in outputs/capacities to represent interactions between oligopolistic firms. Cournot oligopoly game is equivalent to a two-stage game in which firms first choose their outputs/capacities and then set their prices. This type of game is better suited for the representation of long-term behaviour then Bertrand price competition.

[3] There is no domestic production of coal and lignite, natural gas, crude petroleum and uranium and metal ores. However, these commodities are traded with the rest of the world and between the Belgian regions.

Table 3.1 Oligopolistic and monopolistically-competitive sectors in GreenMod II

Oligopolistic sectors	Monopolistically-competitive sectors
Forestry, logging and related service activities	Agriculture, hunting and related service activities
Fishing, operation of fish hatcheries and fish farms	Publishing, printing and reproduction of recorded media
Mining of metal ores	Recycling
Other mining and quarrying	Construction
Manufacture of food products and beverages	Hotels and restaurants
Manufacture of tobacco products	Supporting and auxiliary transport activities; activities of travel agencies
Manufacture of textiles	Real estate activities
Manufacture of wearing apparel; dressing and dyeing of fur	Renting of machinery and equipment without operator
Tanning and dressing of leather	Computer and related activities
Manufacture of wood and of products of wood and cork	Other business activities
Manufacture of pulp, paper and paper products	Education
Manufacture of coke, refined petroleum products and nuclear fuel	Activities of membership organization n.e.c.
Manufacture of chemicals and chemical products	Recreational, cultural and sporting activities
Manufacture of rubber and plastic products	Other service activities
Manufacture of other non-metallic mineral products	Private households with employed persons
Manufacture of basic metals	
Manufacture of fabricated metal products	
Manufacture of machinery and equipment n.e.c.	
Manufacture of office machinery and computers	
Manufacture of electrical machinery and apparatus n.e.c.	
Manufacture of radio, television and communication equipment and apparatus	
Manufacture of medical, precision and optical instruments, watches and clocks	
Manufacture of motor vehicles, trailers and semi-trailers	
Manufacture of other transport equipment	
Manufacture of furniture; manufacturing n.e.c.	
Production and distribution of natural gas	
Production and distribution of nuclear electricity	
Production and distribution of non-nuclear electricity	
Collection, purification and distribution of water	
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	
Wholesale trade and commission trade, except of motor vehicles and motorcycles	
Retail trade, except of motor vehicles and motorcycles	
Land transport; transport via pipelines	
Water transport	
Air transport	
Post and telecommunications	
Financial intermediation, except insurance and pension funding	
Insurance and pension funding	
Activities auxiliary to financial intermediation	
Research and development	
Public administration and defence; compulsory social security	
Health and social work	
Sewage and refuse disposal, sanitation and similar activities	

Costs structure of each oligopolistic and monopolistically-competitive firm consists of variable and fixed costs, where we assume that the firm's fixed costs include the fixed capital costs and the fixed labour costs. Thus, the formulation of capital and labour demand by sector and region is modified by including labour and capital fixed costs depending upon the number of firms in the industry. Sector's marginal costs, which are equal to the marginal costs of the identical oligopolistic firms, are derived based on the total fixed costs of the sector. Prices of oligopolistic sectors are calculated as a mark-up over the marginal costs and depend upon the total number of operating firms. Prices of monopolistically-competitive sectors are calculated as a constant mark-up over the marginal cost, which does not depend upon the total number of operating firms. The equilibrium number of firms in an industry is determined from the zero profit condition.

In each period, capital is assumed to be sector specific. Furthermore, a share of gross output in each sector is assumed to be produced using "malleable" capital, whereas the rest is produced using old capital vintages ("rigid" capital). The technology is assumed to have a putty/semi-putty specification, which implies that possibilities of substitution among factors of production are assumed to be higher for the malleable than for the rigid capital (vintage capital). The older the capital vintage the lower are the substitution possibilities between capital and other factors of production, and thus the lower are the adjustments in factors' demand in response to changes in relative prices. Due to the coexistence of malleable and different generations of non-malleable capital within the same period, substitution effects are delayed over time and demand for production factors adjusts gradually in reaction to relative prices changes (Van der Mensbrugghe, 1994).

Treated at an aggregate level (at regional level) firms receive income from sales of goods, they purchase intermediate inputs, make wage payments, pay social security contributions, corporate income taxes and other taxes on capital use to the regional governments, make transfers to the households, and save.

3.2.3. Backstop technologies

Technical change is well known to have a strong influence on projections of greenhouse gas emissions and the costs of their control. Therefore, GreenMod II incorporates three energy alternatives ("backstop" technologies[4]): a carbon-free electric power generation based on biomass, a carbon-free electric power generation based on wind power and a hydrocarbon-intensive technology for natural gas (coal gasification).

The nested production structure for coal gasification is summarized in Fig. 3.4, while the nested production structure for carbon-free electric power generation based on biomass or on wind power is provided in Fig. 3.5. For coal gasification, producers are assumed to choose at the outer nest intermediate inputs of non-energy goods, coal and a capital-labour bundle *(KL)* bundle, according to a Leontief production function. At the second stage, they choose the optimal level of capital and labour, whereas the substitution possibilities between capital and labour are reflected by a CES function. As already mentioned, gross output of carbon-free electricity based on either biomass or wind power is also determined from a nested production structure. At the first stage, producers choose the optimal level of natural resources and a bundle *(FKLO)* composed of a fixed factor, capital, labour and other non-energy inputs. Thus, both agricultural sectors and backstop electricity sector compete for natural resources. The substitution possibilities between natural resources and the *FKLO* bundle are given by a CES function.

[4] According to Nordhaus (1979), the "backstop" technology represents an energy source which is not yet commercial, but is available in unlimited supply at constant marginal cost and is physically a perfect substitute for a conventional energy input.

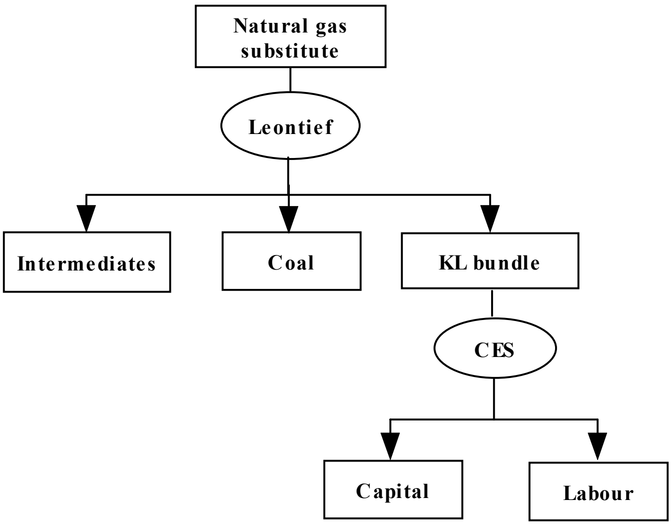

Fig. 3.4. The nested Leontief and CES production technology for coal gasification

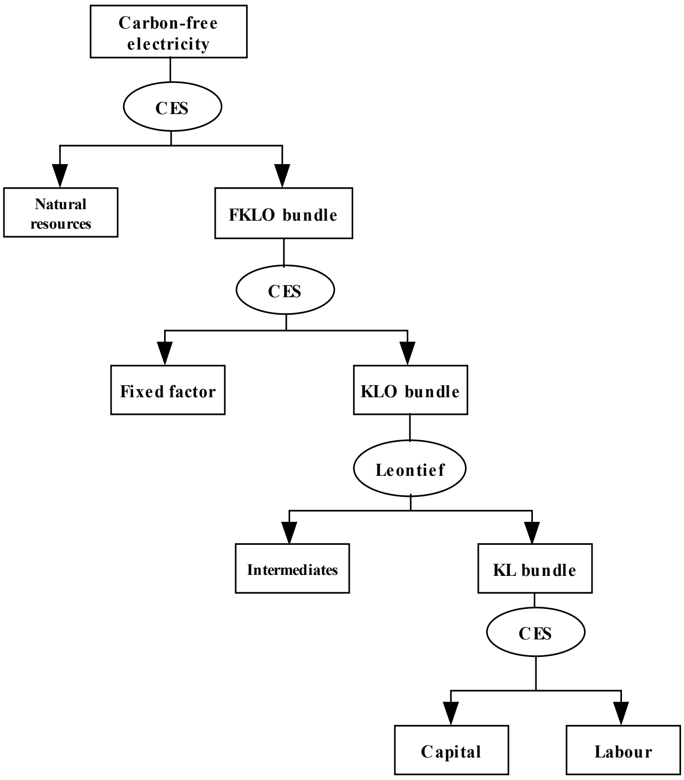

Fig. 3.5. The nested Leontief and CES production technology for carbon-free electric power generation

At the second stage, producers are assumed to choose the optimal levels of fixed factor and a capital-labour-other non-energy inputs *(KLO)* bundle. Substitution possibilities are again reflected by a CES function. The fixed factor is technology-specific and it is introduced to slow the initial penetration of the backstop technologies for electricity. The optimal level of non-energy inputs and the capital-labour *(KL)* bundle is determined at the third stage, according to a Leontief function. The allocation between capital and labour is given at the fourth nest, by another CES function. Thus, the attributes of these new technologies, and the differences between the backstop technology based on biomass and the one based on wind power, are reflected by the parameters of the nested CES functions (Paltsev et al., 2005).

All these new technologies are available in the model at the regional level, but they are assumed to remain uneconomical in the first few years of the GreenMod II simulation horizon. Following Babiker et al. (2001), the backstop technologies are endogenously switched on if they become economically competitive with the existing technologies. Depending on the policy simulation the three backstop technologies may become competitive energy sources in GreenMod II at the same moment or at different moments in time. Backstop natural gas is assumed to be a perfect substitute for the conventional natural gas, while the backstop electricity based on biomass and the one based on wind power are assumed to be perfect substitutes for electricity. Both backstop natural gas and electricity are not traded either between the regions or internationally.

3.2.4. Households

Ten types of households are represented in each region, differentiated according to the income level. Each decile of each region receives labour income originating from the region of residence and from the other two Belgian regions. Commuting activities between the Belgian regions are surprised by the labour income originating from regions different from the household's residence region. Besides labour income from the Belgian resident firms the households also receive labour income from the non-resident firms. Each household group also gets a fixed share of the capital income originating from the region of residence and transfers from the regional and federal governments, from the firms and from the external sector. The transfers from the federal government also include unemployment benefits.

Each decile of each region is endowed with a certain amount of time that is further allocated over labour supply and leisure. The optimal level of leisure demanded by the households is the result of an optimization process. Thus, labour supply by household income group and region is also endogenously determined. The regional labour supply is then given by summing up the amount of labour supplied by each decile of each region.

On the expenditure side, households pay personal income taxes to both federal and regional governments. Personal income tax in Belgium is a co-joined tax. It is a federal tax in the sense that it is applied in a uniform manner on all the territory, but a share of the corresponding revenues is attributed to the regional governments. The regions are authorized to perceive an additional percentage to the tax rate established at federal level or to grant reductions, up to the total amount attributed to each region. Thus, a distinction has been made in the model between the tax rates paid at federal and regional levels.

A share of household net income is saved, whereas the difference between the net income and savings is allocated to the budget disposable for consumption of commodities. Extended budget disposable for consumption further takes into account the opportunity cost of leisure equal to before-tax regional-wide average wage rate. A schematic representation of household decisions for each decile is given in Fig. 3.6.

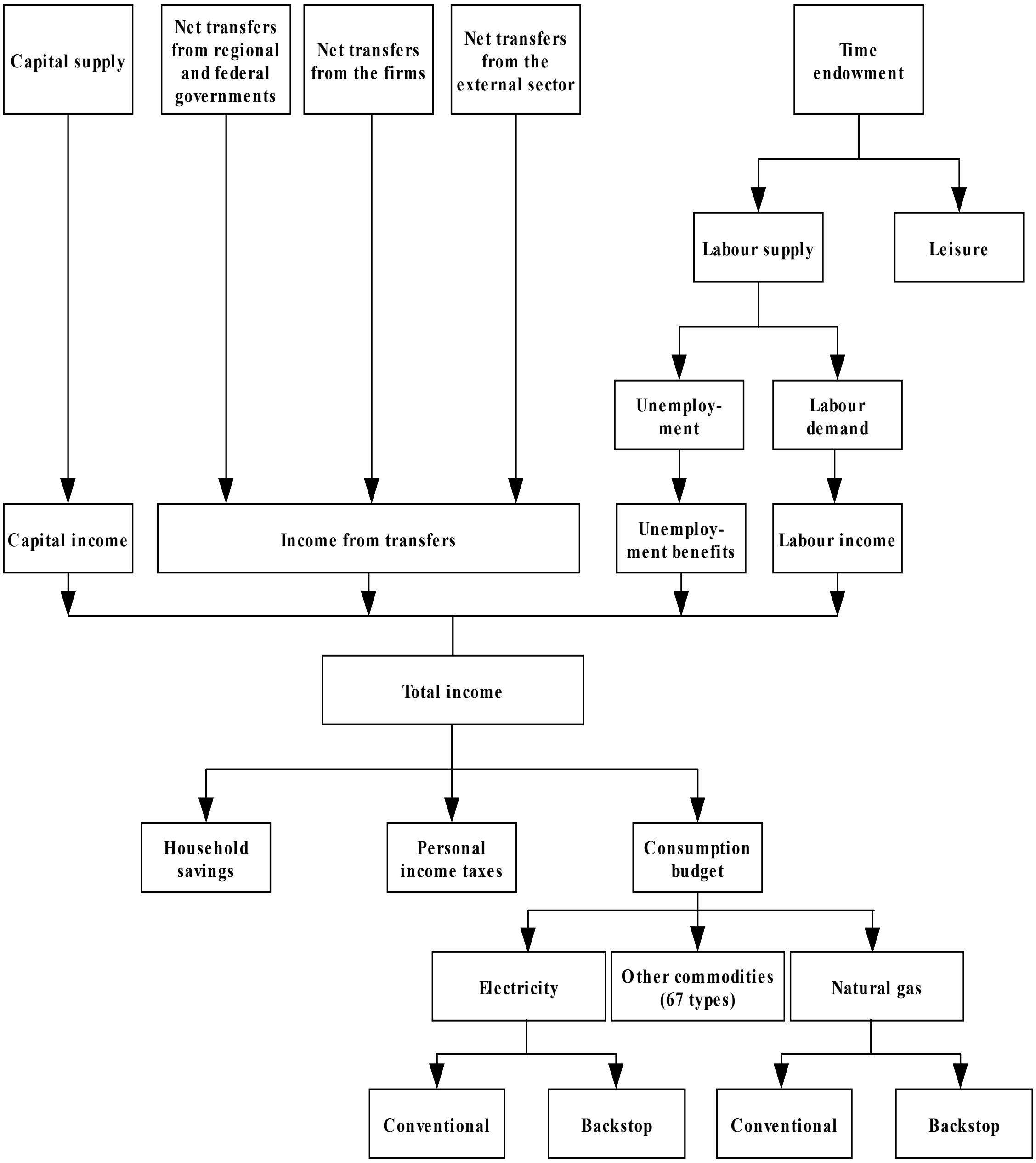

Fig. 3.6. Decision structure of the households, for each decile

Household demand for commodities and leisure is the result of a two-stage optimization procedure. In the first stage, the optimal allocation between a composite consumption commodity $(CC_{d,r})$ and leisure $(CLES_{d,r})$ is given by maximizing a Stone-Geary utility function:

$$U_{CC_{d,r},CLES_{d,r}} = (CC_{d,r} - \mu HC_{d,r})^{\alpha HC_{d,r}} \cdot (CLES_{d,r} - \mu LES_{d,r})^{\alpha LES_{d,r}} \qquad (1)$$

subject to the extended budget constraint:

$$CEBUD_{d,r} = PC_r \cdot CC_{d,r} + (1 - ty_{d,r} - tyf_{d,r}) \cdot PW_r \cdot CLES_{d,r} \qquad (2)$$

with $\alpha HC_{d,r} + \alpha HLES_{d,r} = 1$. The index *d* stands for one of the deciles and *r* for one of the three Belgian regions. The consumer price corresponding to the consumption of composite commodity is given by PC_r, whereas $\mu HC_{d,r}$ and $\mu HLES_{d,r}$ reflect the subsistence levels of consumption of composite commodity and leisure, respectively. Marginal budget shares related to consumption of composite commodity $(\alpha HC_{d,r})$ and leisure $(\alpha HLES_{d,r})$ reflect how the income left after purchasing the subsistence levels of goods is further allocated between the two of them. $tyf_{d,r}$ and $ty_{d,r}$ stand for the personal income tax rates paid at the federal and regional levels, respectively.

In the second stage, the optimal allocation of the composite commodity between consumption of sixty-nine types of commodities $(C_{c,d,r})$ is given by maximizing another Stone-Geary utility function:

$$U_{C_{c,d,r}} = \prod_{c} (C_{c,d,r} - \mu H_{c,d,r})^{\alpha H_{c,d,r}} \tag{3}$$

subject to the budget constraint:

$$CBUD_{d,r} = \sum_{c} (1 - tsc_{c,d,r} - tscf_{c,d,r}) \cdot (1 + tcf_{c,d,r}) \cdot (1 + vat_{c,d,r} + tc_{c,d,r}) \cdot P_{c,r} \cdot C_{c,d,r} \tag{4}$$

with $\sum_{c} \alpha H_{c,d,r} = 1$. The index c stands for one of the sixty-nine types of commodities. The classification of the commodities in GreenMod II is given in section 6.1. As explained, one homogenous commodity is produced by more than one sector, i.e. electricity, and a production sector can produce several types of commodities, i.e. manufacture of coke, petroleum products and nuclear fuels.

Consumption is valued at market prices, including excise, value added taxes and other federal and regional taxes less subsidies on products. Excise duties $(tcf_{c,d,r})$ are applied to commodities prices net of subsidies ($tscf_{c,d,r}$ and $tsc_{c,d,r}$) and are paid to the federal level. Value added taxes $(vat_{c,d,r})$ and other taxes on consumption $(tc_{c,d,r})$ are further applied to prices gross of excise duties.

After some rearrangements the two-stage optimization process generates the demand equations for consumption commodities and for leisure[5]. When the new technologies for natural gas and electricity become competitive energy sources, backstop natural gas and electricity are assumed to be perfect substitutes for their conventional counterparts. Prior to this moment, demand for natural gas and electricity is only given by their conventional counterparts.

Equivalent variation in income is used to evaluate the overall change in consumer welfare of each household group in each region (Varian, 1992). Equivalent variation measures the income needed to make the household as well off as she is in the new counter-factual equilibrium evaluated at benchmark prices. For welfare gains the equivalent variation is positive while for losses is negative (Harrison and Kriström, 1997).

[5] The Linear Expenditure System (LES) was developed by Stone (1954) and represents a set of consumer demand equations linear in total expenditure.

3.2.5. Government

Government behaviour is modelled at three different levels in GreenMod II: federal, regional, and community. At the community level, only the behaviour of the French community is explicitly represented. The Flemish community and the Flemish region share a single government, which exercise the community and regional powers. Therefore, the Flemish community is accounted for together with the Flemish regional government in the model.

Federal government

The attributes regarding the tax collection in Belgium are shared between the federal and regional governments. Tax revenues of the federal government consist of custom duties levied on imports of goods, value added taxes, excise duties and other taxes on consumption of commodities, personal and corporate income taxes, social security contributions, taxes on production and taxes on investment goods. On the expenditure side, a part of the budget is allocated for current consumption of public services, education, health and social work services, a part is used to provide subsidies on consumption and direct subsidies to the firms in the three Belgian regions, another part is transferred to households, regional governments and the French community, and the rest is saved.

Public services, education and health and social work services are assumed to be produced by the corresponding production sectors in the model, using labour inputs, capital inputs, energy inputs and other non-energy inputs. Then, a part of these services is transferred to the federal government. The optimal allocation of consumption by the government among these services is given by the maximization of a Cobb-Douglas utility function:

$$U_{CFG_{c,r}} = \prod_c CFG_{c,r}^{\alpha CFG_{c,r}} \tag{5}$$

subject to the constraint that the government budget disposable for current consumption should be equal to the difference between total tax revenues, government savings and total expenditures on subsidies and transfers, with: $\sum_c \alpha CFG_{c,r} = 1$. The optimization process yields the demand equations for public services, education, health and social work services by the federal government in each region.

Federal government transfers to each household group in each region $(TRHFG_{d,r})$ include unemployment benefits and other transfers $(TRO_{d,r})$ such as pensions:

$$TRHFG_{d,r} = shunempb_{d,r} \cdot trep_r \cdot PW_r \cdot UNEMP_r + TRO_{d,r} \cdot INDEX_r \tag{6}$$

Unemployment benefits are determined by the number of unemployed in each region $(UNEMP_r)$, to which the replacement rate $(trep_r)$ out of the regional net wage (PW_r) is applied. Unemployment benefits are further distributed among the deciles taking into account the share of unemployment benefits received by each household group in each region $(shunempb_{d,r})$. Consumer price index (CPI) at the regional level $(INDEX_r)$, of Laspeyres type, has been used to express other transfers of the federal government to the households in nominal terms.

Regional governments

Regional governments collect taxes on private consumption, taxes on capital use and taxes on production, and an additional percentage to the personal income tax rate established at federal level. Each of the governments also receives transfers from the federal government. Additionally, the Walloon government gets transfers from the French community.

On the expenditure side, all three regional governments allocate a part of their budget to public services and education services. They also subsidize consumption of the resident households and production of the resident firms in the corresponding region. Regional governments also make transfers to the resident households and to the external sector. The difference between total revenues and total expenditures is saved. Transfers to the rest of the world are provided in foreign currency, and transformed in the domestic currency by multiplying them with the exchange rate.

The optimal allocation of current consumption between public services and education services is again given by the maximization of a Cobb-Douglas utility function:

$$U_{CG_{c,r}} = \prod_{c} CG_{c,r}^{\alpha CG_{c,r}} \tag{7}$$

subject to the regional governments budgets disposable for current consumption, whereas $\sum_{c} \alpha CG_{c,r} = 1$.

French community (Communauté Wallonie-Bruxelles)

French community gets all its revenues from the federal government, as transfers. A part of its revenues is further transferred to the Walloon government, whereas the rest is allocated for consumption of public services and education services. Again, the optimal allocation of consumption between these services is given by the maximization of a Cobb-Douglas utility function, yielding the demand equations for the public and education services.

3.2.6. Inter-regional and foreign trade

The specification of foreign trade is based on the small-country assumption. This means that each region is a price taker in both its imports and exports markets. Thus, both import and export prices are fixed exogenously in foreign currency but they are endogenously determined in domestic currency.

The assumption of imperfect substitution possibilities between domestically produced and imported goods, which goes back to Armington (1969), is now a standard feature of applied CGE models and is also adopted here. It indicates that domestic consumers use composite goods $(X_{c,r})$ of imported and domestically produced goods, according to a CES function. Given the regional dimension of the model, the composite (Armington) demand consists of domestically produced goods, imports from the other Belgian regions and imports from the rest of the world (ROW). Because Belgium is a very open economy, substitution possibilities between the imports from the other Belgian regions, imports from ROW and domestically produced goods are assumed to be the same. The Armington trade structure for Brussels region adopted in GreenMod II is given in Fig. 3.7. The trade structure for Flanders and Wallonia are represented in a similar way.

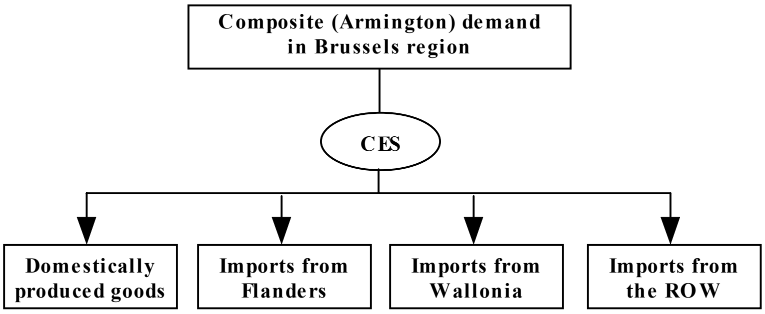

Fig. 3.7. The Armington trade structure in GreenMod II

In GreenMod II each production sector can produce several types of commodities, whereas several sectors can produce the same homogenous good. Therefore, imports from the Belgian regions and domestically produced goods account for the sector of origin and the type of commodity they produce. Imports from the rest of the world only take into account the type of product and their region of destination. For example, in the Brussels region the demand for each category of imports and domestically produced goods is given by the minimization of the cost function:

$$Cost_{M_{c,b},ME_{s,c,f,b},ME_{s,c,w,b},XDD_{s,c,b}} = PM_{c,b} \cdot M_{c,b} + PDM_{s,c,f,b} \cdot ME_{s,c,f,b} + PDM_{s,c,w,b} \cdot ME_{s,c,w,b} + PDD_{s,c,b} \cdot XDD_{s,c,b} \quad (8)$$

subject to the CES function:

$$X_{c,b} = aA_{c,b} \cdot [\, \gamma A1_{c,b} \cdot M_{c,b}^{-\rho A_{c,b}} + \gamma A2_{s,c,b} \cdot ME_{s,c,f,b}^{-\rho A_{c,b}} + \gamma A3_{s,c,b} \cdot ME_{s,c,w,b}^{-\rho A_{c,b}} + \gamma A4_{s,c,b} \cdot XDD_{s,c,b}^{-\rho A_{c,b}} \,]^{-1/\rho A_{c,b}} \quad (9)$$

where $M_{c,b}$ stands for imports of commodity *c* by the Brussels region (*b)* from the rest of the world, $ME_{s,c,f,b}$ stands for imports of commodity *c* by the Brussels region originating from sector *s* of Flanders (*f*), $ME_{s,c,w,b}$ for imports of commodity *c* by the Brussels region originating from sector *s* of Wallonia (*w*), and $XDD_{s,c,b}$ for the domestically produced commodity *c* originating from sector *s* of Brussels. Their corresponding prices in domestic currency are given by $PM_{c,b}$, $PDM_{s,c,f,b}$, $PDM_{s,c,w,b}$ and $PDD_{s,c,b}$, respectively. All three regions share the same currency, such that the prices of imports from Flanders and Wallonia are already expressed in domestic currency. Furthermore, there are no tariffs between the Belgian regions. The efficiency parameter of the CES function is given by $aA_{c,b}$, whereas the distribution parameters for imports from the rest of the world, the imports from Flanders, the imports from Wallonia and for domestically produced goods are given by $\gamma A1_{c,b}$, $\gamma A2_{s,c,b}$, $\gamma A3_{s,c,b}$ and $\gamma A4_{s,c,b}$, respectively. The elasticity of substitution between imports from the Belgian regions, from the rest of the world and domestically produced goods $(\sigma A_{c,b})$ is given by $1/(1+\rho A_{c,b})$. Demand for domestically produced goods, imports from other Belgian regions and imports from the rest of the world in Flanders and Wallonia are derived in a similar fashion as for the Brussels region. Backstop energy inputs are not traded between the regions or with the rest of the world.

The derived Armington demands for domestically produced commodities are directly taken into account by the oligopolistic firms in their profit-maximization problems. The output produced by these firms is equal to the demand they face and this equality determines their oligopolistic price levels.

Imperfect substitution is also assumed to exist between goods produced by the perfectly competitive sectors for the regional domestic market $(XDD_{s,c,r})$ and for exports as captured by a constant elasticity of transformation (CET) function. Again, a distinction is made between exports to the other Belgian regions and exports to the rest of the world. Regional exports take into account for each type of commodity its sector and region of origin and its region of destination. Exports to the rest of the world only account for the sector and region of origin. For example, in Brussels producers maximize their revenues:

$$Revenue_{E_{s,b},EM_{s,c,b,f},EM_{s,c,b,w},XDD_{s,c,b}} = PE_s \cdot E_{s,b} + PDE_{s,c,b,f} \cdot EM_{s,c,b,f} + PDE_{s,c,b,w} \cdot EM_{s,c,b,w} + PDD_{s,c,b} \cdot XDD_{s,c,b} \tag{10}$$

subject to the CET function:

$$XD_{s,b} = aT_{s,b} \cdot [\gamma T1_{s,b} \cdot E_{s,b}^{-\rho T_{s,b}} + \gamma T2_{s,c,b} \cdot EM_{s,c,b,f}^{-\rho T_{s,b}} + \gamma T3_{s,c,b} \cdot EM_{s,c,b,w}^{-\rho T_{s,b}} + \gamma T4_{s,c,b} \cdot XDD_{s,c,b}^{-\rho T_{s,b}}]^{-1/\rho T_{s,b}} \tag{11}$$

to derive the optimal allocation of exports to the rest of the world by sector *s* $(E_{s,b})$, the exports of commodity *c* produced by sector *s* to Flanders $(EM_{s,c,b,f})$, the exports of commodity *c* produced by sector *s* to Wallonia $(EM_{s,c,b,w})$, and the domestic supply of commodity *c* by sector *s* in Brussels $(XDD_{s,c,b})$. Their corresponding prices, in domestic currency are given by PE_s [6], $PDE_{s,c,b,f}$, $PDE_{s,c,b,w}$ and $PDD_{s,c,b}$, respectively. The elasticity of substitution between Brussels exports to Flanders and Wallonia, its exports to the rest of the world and domestically produced goods $(\sigma T_{s,b})$ is provided by $1/(1+\rho T_{s,b})$, whereas $aT_{s,b}$ is the efficiency parameter and $\gamma T1_{s,b}$, $\gamma T2_{s,c,b}$, $\gamma T3_{s,c,b}$ and $\gamma T4_{s,c,b}$ are the distribution parameters for exports to the rest of the world, exports to Flanders, exports to Wallonia and domestically supplied goods, respectively. Exports and domestic supply of Flanders and Wallonia are derived in a similar manner as for the Brussels region.

The regional characteristic of the model imposes an obvious restriction: the exports of a Belgian region to another Belgian region represent the imports of the later from the former. For example, the exports of Brussels to Wallonia are equal to the imports of Wallonia from Brussels. As there are no tariffs on imports between the regions, the same equality stands for prices.

[6] Export price by sector *s* to the rest of the world, expressed in domestic currency, is equal for all three regions because the regions have a common exchange rate and the international prices of exports are given by the external market.

The use of the CET transformation function for the imperfectly competitive sectors is redundant, since their output levels are equal to the Armington demands in accordance with the formulation of their profit-maximization problems.

The balance of payments at the national level is further given by all international incoming and outgoing payments in foreign currency. The surplus or the deficit of the balance of payments (SWT) is thus derived by the difference between exports and imports, valued at world market prices, $PWEZ_s$ and $PWMZ_c$, respectively, the transfers of the regional governments $(TRWG_r)$ to the external sector, the transfers received by each household group $(TRHW_{d,r})$ from the external sector as well as the payments for labour supplied to the non-resident firms (LW_r). The net wage rate paid by the non-resident firms $(PLWZ)$, expressed in foreign currency, is fixed exogenously.

$$SWT = \sum_c \sum_r M_{c,r} \cdot PWMZ_c - \sum_d \sum_r TRHW_{d,r} + \sum_r TRWG_r - \sum_s \sum_r E_{s,r} \cdot PWEZ_s - \sum_r LW_r \cdot PLWZ \quad (12)$$

The surplus/deficit of the balance of payments reflects the net lending/borrowing of the economy to/from the rest of the world.

3.2.7. Investment demand

Total savings are derived at national level, because it is not possible to distinguish federal government and foreign savings at regional level. The demand for investment commodities is differentiated instead by region and type of commodity.

National savings (S) are given by the household savings, firms savings, federal and regional governments savings, foreign savings and the depreciation. The allocation of savings between different types of investment goods demanded in each region $(I_{c,r})$ is given by the maximization of a Cobb-Douglas utility function:

$$U_{I_{c,r}} = \prod_c \prod_r I_{c,r}^{\alpha I_{c,r}} \quad (13)$$

subject to the constraint that savings less changes in stocks should be equal to the total expenditures on investment goods, where $\alpha I_{c,r}$ represent the Cobb-Douglas share parameters with $\sum_c \sum_r \alpha I_{c,r} = 1$. Expenditures on investment goods also include the value added taxes and other taxes on purchases of investment commodities, paid to the federal government. The optimization process yields the demand equations for investment goods by type of commodity and region.

No information is available on the composition of investments carried out in the sectors. Therefore, in the dynamic part of the model it has been assumed that a composite homogenous good is invested in each sector. The price of the composite investment commodity (PI) is derived according to the Cobb-Douglas unit expenditure function:

$$PI = \prod_{c}\prod_{r}[P_{c,r} \cdot (1 + vati_{c,r} + tci_{c,r}) / \alpha I_{c,r}]^{\alpha I_{c,r}} \tag{14}$$

where $P_{c,r}$ is the price of the composite commodity c in region r from imports and regional domestic supply, $vati_{c,r}$ is the value added effective tax rate and $tci_{c,r}$ is the effective tax rate corresponding to other taxes on purchases of investment goods.

Changes in stocks are modelled as a fixed share of the composite supply of commodities, coming from imports and regional domestic supply.

3.2.8. Price equations

Initial price levels of the commodities produced by the oligopolistic and monopolistically-competitive sectors are derived according to the mark-up pricing rule, using information about the levels of their fixed costs and the initial number of operating firms in each industry. They can be either greater or less than unity.

Due to the homogeneity of degree zero in prices, the model only determines relative prices. Therefore, a particular price is selected to provide the numeraire price level against which all relative prices in the model are measured. In this case, the GDP deflator at the national level is chosen as the numeraire.

Different prices are distinguished for all producing sectors at regional level, consumption goods, exports and imports. Domestic prices of exports to the rest of the world are determined by the world prices and the exchange rate, whereas domestic prices of imports from the rest of the world are determined by the world prices, the exchange rate and the tariff rates. Given that the composition of the import bundle corresponding to each commodity in GreenMod II is different at regional level, the effective tariff rates are also different at regional level, such that domestic prices of imports to the rest of the world are distinguished by type of commodity and region.

Consumer price indexes of Laspeyres type are defined at both regional and national levels. GDP deflator at national level is defined by the ratio of GDP at current market prices to GDP at constant prices.

3.2.9. Labour market

As discussed in section 3.2.2, labour services are used by firms in the production process. Commuting activities are important between the regions, especially those from Flanders and Wallonia towards Brussels. In the model, the number of commuters is determined as a fixed share of the total labour demand in the region they are employed. As a consequence, each household group can earn its income in one region and spend it in a different one.

Regional labour markets are closed by changes in unemployment:

$$\sum_{sbk} L_{sbk,b} = LSR_b + shWBx \cdot \sum_{sbk} L_{sbk,b} + shFlBx \cdot \sum_{sbk} L_{sbk,b} - UNEMP_b \tag{15}$$

$$\sum_{sbk} L_{sbk,f} = LSR_f - shFlBx \cdot \sum_{sbk} L_{sbk,b} + shWFl \cdot \sum_{sbk} L_{sbk,f} - UNEMP_f \tag{16}$$

$$\sum_{sbk} L_{sbk,w} = LSR_w - shWBx \cdot \sum_{sbk} L_{sbk,b} - shWFl \cdot \sum_{sbk} L_{sbk,f} - UNEMP_w \qquad (17)$$

where $L_{sbk,r}$ provides the number of employed by sector (including the backstop technologies when they become economically competitive) in each region, LSR_r represents the regional labour supply to resident firms and $UNEMP_r$ gives the regional unemployment level. As before, subscripts *b*, *f*, *w* stand for Brussels, Flanders and Wallonia, respectively. The share of commuters from Wallonia to Brussels is given by $shWBx$, the share of commuters from Wallonia to Flanders by $shWFl$, whereas the share of commuters from Flanders to Brussels is given by $shFlBx$.

Regional labour supply to resident and non-resident firms (LS_r) is further given by:

$$LS_r = LSR_r + LW_r \qquad (18)$$

GreenMod II incorporates the representation of wage bargaining between the trade unions and firms. The bargaining process determines the level of wages in different sectors and regions. The bargaining process outcome depends upon the optimization functions of the two participating agents: firms and trade unions. Trade unions maximize their utility function that depends on the total wage of their members which are employed and total unemployment benefits of the unemployed ones. Firms on the other hand try to maximize their profits. As a result, the total profits of the firms are shared between the firms and the workers, in a proportion depending on the trade unions bargaining power:

$$PL_{s,r} = PLU_{s,r} - (1 - \alpha B) \cdot scalB_{s,r} \cdot PROFITS_{s,r} / [L_{s,r} \cdot (1 + tl_{s,r})] \qquad (19)$$

where $PLU_{s,r}$ is the worker's reservation wage reflecting the expected income associated with his alternative option: not to take the job; αB is the power of the trade union's utility function associated with the total wages of its members which are employed; $scalB_{s,r}$ is the bargaining power of trade union in sector *s* in region *r*; $PROFITS_{s,r}$ are the profits of sector *s* in region *r*; and $tl_{s,r}$ is the social security contribution rate paid by the firms. The worker's reservation wage is calculated according to the following formula:

$$PLU_{s,r} = (1 - PR_r) \cdot PLZ_{s,r} \cdot INDEX_{s,r} \cdot trep_r + PR_r \cdot PW_r \qquad (20)$$

and is equal to the regional specific probability to be unemployed $(1 - PR_r)$ multiplied by the unemployment benefits (calculated as the last period wage $PLZ_{s,r}$, indexed with the consumer price level $INDEX_r$, and multiplied by the regional replacement rate $trep_r$), plus the probability to be employed $PR_{s,r}$ multiplied by the average wage PW_r received by the residents of the region *r*.

The functioning of the labour market in GreenMod II follows the search and matching model of Pissaridies (2000). In each period, firms post a certain number of vacancies on the labour market, depending on the required level of employment, where the necessary number of vacancies $NV_{s,r}$ is determined by the following formula:

$$NV_{s,r} = (L_{s,r} - LZ_{s,r} + \mu \cdot LZ_{s,r}) / QR_{s,r} \qquad (21)$$

where μ is the job separation rate (the share of workers fired because they did not completely match the profile of their jobs) and $QR_{s,r}$ is the probability to fill in a vacancy.

The firms pay a certain unit cost per each posted vacancy $wv_{s,r}$ such that the total search costs $CSEARCH_{s,r}$ of sector *s* in region *r* is equal to:

$$CSEARCH_{s,r} = NV_{s,r} \cdot wv_{s,r} \cdot INDEX_r \qquad (22)$$

Unemployed people search for jobs. However, not every search-job match is successful because of the individual qualities of the workers. Successful matches, leading to further employment, $NM_{s,r}$ are formed according to the matching function from vacancies $NV_{s,r}$ and unemployed people $UNEMP_r$. The matching function in GreenMod II has the following functional form:

$$NM_r = aM_r \cdot [\sum_s NV_{s,r}]^{\alpha M_r} \cdot UNEMP_r^{1-\alpha M_r} \qquad (23)$$

where aM_r is the scaling parameter of the matching function and αM_r is the power of the Cobb-Douglas function associated with the total number of vacancies in the region.

The probability to find a job (PR_r) in region *r* and the probability to fill in the vacancy (QR_r) are further determined as:

$$PR_r = NM_r / UNEMP_r \qquad (24)$$

$$QR_r = NM_r / \sum_s NV_{s,r} \qquad (25)$$

3.2.10. Market clearing equations

Equilibrium on the products, capital and labour markets requires that demand equals supply at prevailing prices (taking into account unemployment for the labour market). Regional labour markets clearing equations have already been presented above (see Eqs. (15)-(17)). Installed capital stock is sector and region specific. Therefore the capital markets clearing equations have been dropped. Conventional and backstop natural gas sectors, when economically competitive, share the same capital market. In a similar way, conventional and backstop electricity sectors share the same capital market in each region.

Separate market clearing equations are distinguished in the model for each non-energy and energy good. For the non-energy goods, the sum of demand for non-energy intermediate inputs by the sectors, of demand for public and private consumption, of demand for investment goods and inventories must equal the supply of non-energy composite goods from imports and domestic supply.

For each energy input, except natural gas and electricity, composite supply from imports and domestic supply should equal the sum of private consumption, of intermediate consumption by the sectors and of demand for inventories.

Market clearing equations for natural gas and electricity are similar to those corresponding to other energy inputs. However, when the backstops for natural gas and/or electricity become competitive energy sources their production level is added to the supply of conventional natural gas and/or electricity from imports and domestic supply. As already mentioned, backstop natural gas and electricity are assumed to be perfect substitutes for conventional natural gas and electricity.

3.2.11. Greenhouse gas emissions

The main part of greenhouse gases emissions in Belgium is given by the CO_2 emissions, which represented about 83.2 per cent of the total in 1990. Another 8.7 per cent in 1990 was provided by N_2O, 8 per cent by CH_4, whereas the other greenhouse gasses (hydrofluorocarbons – HFC, perfluorocarbons – PFC and sulphur hexafluoride – SF6) accounted for less than 1 per cent. In the context of rising greenhouse gases emissions, the shares of CH_4 and N_2O have declined in time due to the reduction of emissions originating from the agricultural and waste sectors.

CO_2 emissions on fuel combustion, generated by the consumption of fuels by each sector of each region are derived by applying the emission factors corresponding to each fuel to the energy consumption by the sectors. Similarly, the CO_2 emissions generated by the consumption of fuels for heating and transport by the households are also derived by applying the emission factors to the consumption of energy by the households.

The CO_2 process emissions originate from the manufacture of chemicals and chemical products, manufacture of other non-metallic mineral products and manufacture of basic metals. They give less than 10 per cent of the total CO_2 emissions. The CO_2 process emissions are linked to the level of production by the specific sector.

GreenMod II allows for different aggregations with regard to CO2 emissions: by sector at the national level, by sector and region, by fuel, sector and region, by region (including or excluding households' emissions). The CO_2 emissions are expressed in kilotons (kt).

The vast majority of methane emissions in Wallonia and Flanders originate from the agricultural and waste sector. Compared to the CO_2 emissions, only a small share of their total comes from the fuel combustion directly. On the contrary, in Brussels 99.9 per cent of the total CH_4 emissions is given by fuel combustion. The CH_4 emissions generated by the fuel combustion are derived by applying the emissions factors to the consumption of fuels by the sectors, whereas the CH_4 process emissions are linked to the level of production of the responsible sector.

The majority of nitrous oxide emissions in Wallonia and Flanders come from the agricultural sector and from the industrial process of the chemical sector. The level of N_2O emissions in

Brussels is very low relative to the other Belgian regions. They are mainly generated by the use of N_2O for anesthesia, and by fuel combustion by different sectors. The N_2O emissions generated by fuel combustion and the N_2O process emissions are modelled similarly to the CH_4 emissions. Both CH_4 and N_2O emissions are expressed in kilotons (kt) of CO_2 equivalent.

3.2.12. Incorporation of dynamics

GreenMod II has a recursive dynamic structure composed of a sequence of several temporary equilibria. The first equilibrium in the sequence is given by the benchmark year. In each time period, the model is solved for an equilibrium given the exogenous conditions assumed for that particular period. The equilibria are connected to each other through capital accumulation. Thus, the endogenous determination of investment behaviour is essential for the dynamic part of the model. Investment and capital accumulation in year *t* depend on expected rates of return for year $t+1$, which are determined by actual returns on capital in year *t*.

The expected rate of return required to maintain indefinitely the current rate of capital growth in sector *s* of region *r* for the "malleable" part of the capital $(ROR_{s,r,t})$ is specified as an inverse logistic function (see Fig. 3.8) of the proportionate growth in sector's *s* of region's *r* capital stock (Dixon and Rimmer, 2002):

$$\begin{aligned} ROR_{s,r,t} &= RORZ_{s,r} + (1/B_{s,r}) \cdot [ln(KSKg_{s,r,t} - KSKg\,min_{s,r}) - \\ &ln(KSKg\,max_{s,r} - KSKg_{s,r,t}) - ln(KSKtrend_{s,r} - KSKg\,min_{s,r}) + \\ &ln(KSKg\,max_{s,r} - KSKtrend_{s,r})] \end{aligned} \qquad (26)$$

where $RORZ_{s,r,t}$ is the sector's *s* historically normal rate of return, $KSKg_{s,r,t}$ is the capital growth rate in sector *s* in year *t*, $KSKg\,min_{s,r}$ and $KSKg\,max_{s,r}$ are the minimum and the maximum possible growth rates of capital stock in sector *s*, $KSKtrend_{s,r}$ is the sector's historically normal growth rate and $B_{s,r}$ is a positive parameter. The minimum possible growth rate is set at the negative of the rate of depreciation in sector *s*. This condition implies that investments in each sector of each region have positive values, such that once installed, capital cannot be shifted from one sector to another except for the gradual process of depreciation. The maximum possible growth rate of capital stock in sector *s* is set at $KSKtrend_{s,r}$ plus 0.06 in order to avoid unrealistically large simulated growth rates (Dixon and Rimmer, 2002). For example, if the historically normal growth rate in a sector is 4 per cent, the upper limit in any year *t* would not exceed 10 per cent.

Parameter $(B_{s,r})$ reflects the sensitivity of capital growth in sector *s* of region *r* to variations in its expected rate of return. It is derived by differentiating equation (26) with respect to $KSKg_{s,r,t}$:

$$B_{s,r} = SEA \cdot \left[\frac{KSKg\,max_{s,r} - KSKg\,min_{s,r}}{(KSKg\,max_{s,r} - KSKtrend_{s,r}) \cdot (KSKtrend_{s,r} - KSKg\,min_{s,r})} \right] \qquad (27)$$

where:

$$SEA = \left(\frac{\partial ROR_{s,r,t}}{\partial KSKg_{s,r,t}} \right)^{-1} \tag{28}$$

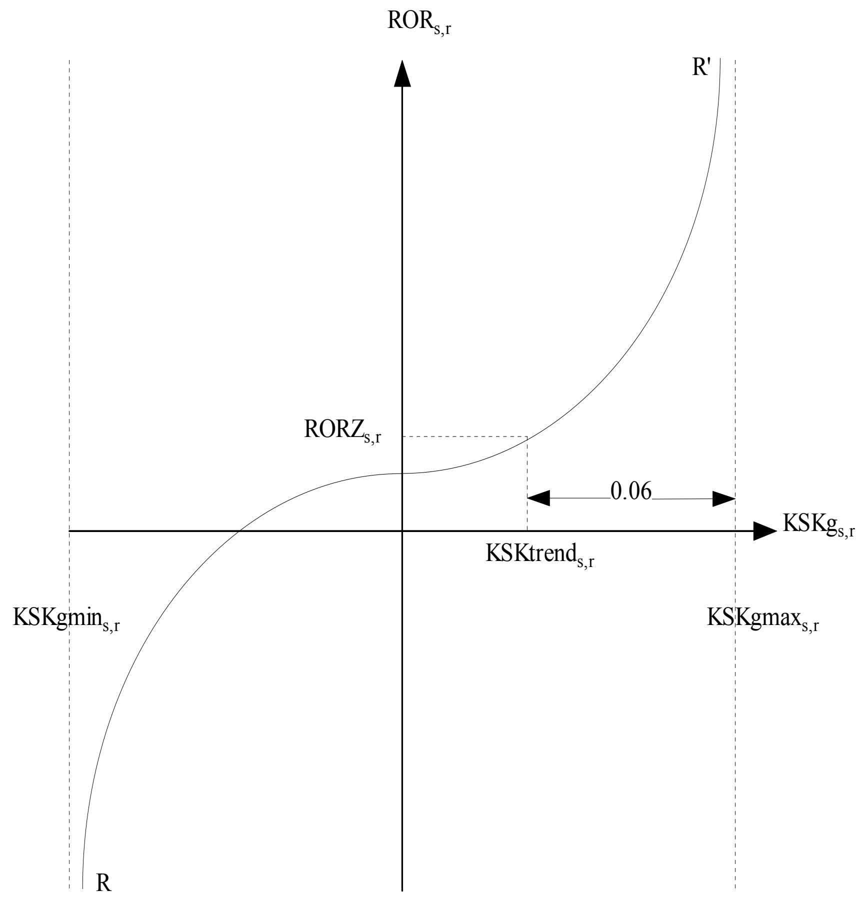

Fig. 3.8. The expected rate of return for sector s of region r

Evaluating (28) in the vicinity of $KSKg_{s,r,t} = KSKtrend_{s,r}$ provides:

$$SEA = \left(\frac{\partial ROR_{s,r,t}}{\partial KSKg_{s,r,t}} \Big|_{KSKg_{s,r,t} = KSKtrend_{s,r}} \right)^{-1} \tag{29}$$

where SEA is the reciprocal of the slope of the RR′ in Fig. 3.8, which is considered to be the same for all sectors in all regions due to the lack of detailed sectoral estimates.

The present value $(PVK_{s,r,t})$ of investing a unit of capital in sector *s* of region *r* in year *t* is defined as:

$$PVK_{s,r,t} = -PI_t + [RKm_{s,r,t+1} + PI_{t+1} \cdot d_{s,r} + PI_{t+1} \cdot (1 - d_{s,r})] / [1 + NINT_t] \tag{30}$$

where PI_t is the cost of buying a unit of capital (the price of composite investment good) in year *t*, $RKm_{s,r,t} + PI_{t+1} \cdot d_{s,r}$ is the rental rate on sector's *s* of region *r* "malleable" capital, $d_{s,r}$ is the depreciation rate in sector *s* of region *r* and $NINT_t$ is the nominal interest rate in year *t* (Dixon and Rimmer, 2002). The purchase of one unit of "malleable" capital in year *t* by sector *s* involves an immediate expenditure (PI_t), followed by two benefits in year $t+1$ which are discounted by $(1+NINT_t)$: the rental value of an extra unit of capital in year $t+1$ $(RKm_{s,r,t+1} + PI_{t+1} \cdot d_{s,r})$, including the depreciation, and the value at which the depreciated unit of capital can be sold in year $t+1$ $[PI_{t+1} \cdot (1-d_{s,r})]$.

The expected rate of return on investment in sector *s* of region *r* in year *t* is further given by dividing both sides of (30) by PI_t:

$$ROR_{s,r,t} = -1 + [RKm_{s,r,t+1} / PI_t + PI_{t+1} / PI_t] / [1 + NINT_t] \quad (31)$$

Under static expectations, investors are assumed to expect that asset prices (the cost of buying a unit of capital) and net rental rates will increase by the current rate of inflation (INF_t). Thus, the expected rate of return $(ROR_{s,r,t})$ under static expectations is derived as:

$$\begin{aligned} ROR_{s,r,t} = -1 + [RKm_{s,r,t} \cdot (1+INF_t) / PI_t + PI_t \cdot (1+INF_t) / PI_t] \\ /[1+NINT_t] \end{aligned} \quad (32)$$

Further simplifying, we arrive at:

$$ROR_{s,r,t} = -1 + [RKm_{s,r,t} / PI_t + 1] / (1 + RINT_t) \quad (33)$$

where we used the fact that the real interest rate $(RINT_t)$ is defined as:

$$1 + RINT_t = (1 + NINT_t) / (1 + INF_t) \quad (34)$$

The weighted average return to capital has been taken as a proxy for the real interest rate in GreenMod II, where the return to capital is expressed in real terms using the production price index.

The "malleable" capital stock in sector *s* of region *r* in the next period (year $t+1$) is given by:

$$KSKm_{s,r,t+1} = (1-d_{s,r}) \cdot (1-\phi_{s,r}) \cdot KSKm_{s,r,t} + INV_{s,r,t} \quad (35)$$

where $KSKm_{s,r,t}$ is the current "malleable" capital stock (in year *t*) and $\phi_{s,r}$ is a "vintage" parameter which determines the share of "malleable" capital that becomes "rigid" each year.

The "malleable" capital growth rate in terms of capital stock in year $t+1$ and the capital stock in year *t* is given by:

$$KSKg_{s,r,t} = KSKm_{s,r,t+1} \,/\, KSKm_{s,r,t} - 1 \tag{36}$$

whereas the actual growth rate of "malleable" capital in sector *s* of region *r* can be derived from Eq. (26) as:

$$\begin{aligned} KSKg_{s,r,t} = & \left[e^{B_{s,r} \cdot (ROR_{s,r,t} - RORZ_{s,r,t})} \cdot KSKg\,max_{s,r} \cdot (KSKtrend_{s,r} - \right. \\ & \left. KSKg\,min_{s,r}) + KSKg\,min_{s,r} \cdot (KSKg\,max_{s,r} - KSKtrend_{s,r}) \right] / \\ & \left[\alpha ROR_{s,r,t} \cdot (KSKtrend_{s,r} - KSKg\,min_{s,r}) + (KSKg\,max_{s,r} - \right. \\ & \left. KSKtrend_{s,r}) \right] \end{aligned} \tag{37}$$

Investments in sector *s* of region *r* in year *t* are derived from Eqs. (35)-(37) as:

$$\begin{aligned} INV_{s,r,t} = & KSKm_{s,r,t} \cdot \{ [e^{B_{s,r} \cdot (ROR_{s,r,t} - RORZ_{s,r,t})} \cdot KSKg\,max_{s,r} \cdot (KSKtrend_{s,r} \\ & - KSKg\,min_{s,r}) + KSKg\,min_{s,r} \cdot (KSKg\,max_{s,r} - KSKtrend_{s,r})] / \\ & [e^{B_{s,r} \cdot (ROR_{s,r,t} - RORZ_{s,r,t})} \cdot (KSKtrend_{s,r} - KSKg\,min_{s,r}) + (KSKg\,max_{s,r} - \\ & KSKtrend_{s,r})] + 1 \} - KSKm_{s,r,t} \cdot (1 - \phi_{s,r}) \cdot (1 - d_{s,r}) \end{aligned} \tag{38}$$

In period $t+1$ the first vintage of non-malleable capital is given as a share $\phi_{s,r}$ of the malleable capital after depreciation:

$$KSKv_{s,v,r,t+1} = \phi_{s,r} \cdot (1 - d_{s,r}) \cdot KSKm_{s,r} \qquad \text{for v = 1} \tag{39}$$

The other (older) vintages in each sector are updated in the dynamic part according to:

$$KSKv_{s,v+1,r,t+1} = (1 - d_{s,r}) \cdot KSKv_{s,v,r,t} \qquad \text{for v = 2,3,...} \tag{40}$$

The model is solved dynamically with annual steps. The simulation horizon of the model has been set at 25 years but it can easily be extended. In between periods, some other variables like the transfers between firms, government and the rest of the world, and the foreign savings are updated exogenously.

3.2.13. Closure rules

The closure rule refers to the manner in which demand and supply of commodities, the macroeconomic identities and the factor markets are equilibrated ex-post. Due to the complexity of the model, a combination of closure rules is needed. The particular set of closure rules should also be consistent, to the largest extent possible, with the institutional structure of the economy and with the purpose of the model.

To balance the number of endogenous variables and the number of independent equations in the model for each year, additional assumptions are needed. Therefore, the transfers between the regional and federal government, households, firms and the rest of the world corresponding to each region are exogenously fixed in real terms. To achieve the regional labour market clearing, inter-sectoral mobility of labour is assumed. However, the presence of unemployment and wage bargaining mechanism introduces rigidities in the labour market. Time endowment is fixed and allocated between labour supply and leisure. Installed capital is sector specific, introducing rigidities on the capital market.

The most widely accepted macro closure rule for CGE models implies the assumption that investment and savings balance. In the model, the investment is assumed to adjust to the available domestic and foreign savings. This reflects an economy in which savings form a binding constraint. The interest rate is assumed to effectively balance the supply and demand for investments, even if the specific mechanism is not incorporated in the model. This macro closure rule is neoclassical in spirit. However, the model also allows for unemployment. As already mentioned, in models of this size it is not uncommon that a few closure rules are combined to get as close as possible to a realistic representation of the economy.

The government behaviour at the federal and regional level is modelled through an optimization process, which yields the optimal allocation of governments' consumption by type of commodity and region. The budget deficits/surpluses of federal and regional governments are exogenously fixed in real terms. With regard to the external sector, the surplus/deficit of the current account is fixed and the endogenous exchange rate brings the balance of payments into equilibrium.

According to Walras' law if (*n-1*) markets are cleared the n^{th} one is cleared as well. Therefore, in order to avoid over-determination of the model, balance of payments equation (Eq. (12)) has been dropped. However, the system of equations guarantees, through Walras' law, that its balance is equal to the difference between the exports and imports and the transfers from and to the rest of the world.

3.3. Construction of a microsimulation model for Belgium linked with GreenMod II

3.3.1. Introduction

Currently, the importance of the microsimulation approach is increasing due to the necessity to understand precisely the effects of economic changes on the individual behaviour and welfare. Improvements in software capacity and survey quality are the driving forces in the development of this approach. Microsimulation approach is used to evaluate the redistributive effects of economic policy shocks. By using detailed information on income sources, residence and consumption patterns, social and demographic characteristics of individual persons, households or population groups, the microsimulation approach significantly improves the results of policy analysis.

Two different microsimulation approaches have been developed in the recent years. First approach, the so-called "integrated approach", consists of representing behaviour of different types of individuals, households or population groups directly within the CGE modelling framework. Another approach, the so-called "layered approach", consists of linking the CGE model with the microsimulation model through a set of exogenous variables.

The "integrated approach" has been used by Cogneau and Robillard (2000) to analyze growth, income distribution and poverty in Madagascar, by Cockburn (2001) to investigate the effects of trade liberalization and poverty in Nepal, by Boccanfusso et al. (2003) to study poverty and income distribution in Senegal, by Savard (2003) to explore the income distribution and poverty in Russia and by Rutherford (2004) to evaluate the effects of Russia's accession to WTO. Most of these studies relate to developing or transition economies and investigate growth and poverty issues.

The major drawback of the studies using the "integrated approach" is the absence of a detailed commodity disaggregation. This results in a poor representation of household consumption preferences. The poor commodity disaggregation in these studies can be explained by both the specific consumption structure in the developing economies and the difficulty to find reliable data. Another reason stands in the computation difficulties associated with solving a CGE model with a large number of both commodity and household groups.

An interesting example using the "layered approach" is the paper by Robillard, Bourguignon and Robinson (2001). This paper analyzes the Indonesian financial crisis of 1997 and its effects on inequality and poverty.

The work by Savard (2003) represents a bridge between the two approaches. It develops an algorithm for solving an integrated CGE and microsimulation model. However, the developed algorithm does not guarantee the existence and the uniqueness of the model solution.

To develop the microsimulation model for Belgium we used the "layered approach", which is more transparent, easier to implement and requires lower computational effort than the "integrated approach". The "layered approach" also allows for a detailed disaggregation of commodities.

Our approach is similar to the one used by Robillard, Bourguignon and Robinson (2001). The Belgian CGE model (GreenMod II) integrates 62 production sectors and 69 types of commodities. GreenMod II is linked with the microsimulation model for Belgium through a set of exogenous variables such as prices and transfers.

The microsimulation model developed within this project is important in light of the regional policy changes in Belgium. By accounting for heterogeneity in income sources and consumption patterns at individual and household level we are able to conduct detailed analysis for a variety of regional, national and international economic policy measures. The microsimulation model is based on the household budget survey.

3.3.2. Methodology

The methodological approach used in developing the microsimulation model for Belgium is based on the work of Robillard, Bourguignon and Robinson (2001). Their model consists of a set of equations describing income behaviour of employees, self-employed, total household income and the occupational choices made by the households' members, including the choices between being a wage worker, self-employed or inactive. The household income is a function of the characteristics and choices of its members.

The model for Belgium distinguishes the wage income, the income of self-employed members of the household, the capital income and the social benefits. As opposed to Robillard, Bourguignon and Robinson (2001) we do not differentiate labour force by market segment. Each equation of the model is defined in terms of individual characteristics of a household member. Their main characteristics include age, education level, occupation, consanguinity with the reference person, residence location and sex. The estimation of model parameters is performed with Eviews using Ordinary Least Squares (OLS). The link between the CGE and the microsimulation model is implemented in GAMS. The overall logic of linking the microsimulation model with the CGE model for Belgium consists in running them sequentially and using outputs provided by the CGE model, such as price and tax levels, as exogenous variables in the microsimulation model.

To illustrate the way the microsimulation model works, we use an example. Suppose the government rises consumption tax rate for a commodity *c* from its initial level $tc0_c$ to a new level tc_c. Let's assume that there is only one source of income in the economy: the labour income. We denote by $PL_{m,r}$ the labour income of a person *m* in region *r*. Let PLG_r be for the final total labour income in region *r*. $PZ_{c,r}$ denotes the price of commodity *c* in region *r* before the tax reform and $P_{c,r}$ the same price after the tax reform. $CZH_{c,h,r}$ stands for the consumption of commodity *c* by household *h* in region *r* and $INDEXH_{h,r}$ for the price index.

We would like to estimate the influence of the reform on each individual person, using the microsimulation model. The microsimulation model consists of individual labour income equations (see Eq. (41)), where $CA_{i,m,r}$ stands for the individual characteristic *i* of person *m* in region *r*; the regional income equations (see Eq. (42)); the price index equations (see Eq. (43)) formulated for each individual household *h* according to its specific consumption bundle; and the real income equations (see Eq. (44)) formulated for each individual person depending on the household he belongs to.

$$log(PL_{m,r}) = \alpha_r + \sum_i \beta_{i,r} CA_{i,m,r} + \varepsilon_{i,m,r} \tag{41}$$

$$PLG_r = \sum_m PL_{m,r} \tag{42}$$

$$INDEXH_{h,r} = \sum_m \frac{(1+tc_{com}) \cdot P_{com,r} \cdot CZH_{com,h,r}}{(1+tc0_{com}) \cdot PZ_{com,r} \cdot CZH_{com,h,r}} \tag{43}$$

$$YR_{m,r} = \frac{1}{INDEXH_{h,r}} PL_{m,r} \tag{44}$$

We first estimated the coefficients in Eq. (41) using the OLS method, employing observations from the initial dataset. Then, we run the regional CGE model to estimate the effects of changes in the commodity tax rates in terms of new commodity price levels $P_{c,r}$ and new total regional income PLG_r. We further assume that PLG_r, α_r and $\beta_{i,r}$ are exogenously given and solve the system of Eqs. (41)-(42) in order to find new levels of residual $(\varepsilon_{i,m,r})$ and individual labour income $(PL_{m,r})$. Given these values, we can calculate the economic effects of the reform in terms of changes in individual nominal and real income $(YR_{m,r})$, according to Eqs. (43)-(44).

3.3.3. Model dataset

The data used to develop the microsimulation model is taken from the Household Budget Survey (HBS), carried out by the Belgian National Institute of Statistics. The survey covers the years 1997-1998 and contains data on 2213 households and 3437 household members together with their professional income or benefits. The database distinguishes the three Belgian regions (Flanders, Wallonia and Brussels).

The survey contains data by household and by household member, including income data and expenditure data. The household income represents the disposable income and contains income from the economic activity, capital income, social security transfers, other benefits and an income tax adjustment. Other benefits contain disability benefits, family allowances, payments by social insurance companies, transfers between families, payments by insurance companies, other social benefits and other transfers. The survey also contains the socio-economic characteristics of the household and household members including age, level of education, occupation, sex and consanguinity with the reference person. The reference person is often a father or a person earning the main income in the household.

Our model represents the disposable income as being composed of wage income, income of self-employed members of the household, capital income, unemployment benefits, pensions, other benefits and income tax adjustment. The wage income, the income of self-employed persons, the unemployment benefits and pensions are differentiated by household member, whereas capital income, other benefits and income tax adjustment are differentiated only by household.

Given that our model includes the representation of the behaviour of individual persons, we split capital income, other benefits and the income tax adjustment between the household members according to the share of their total individual income.

Besides income variables, the model also includes socio-economic variables like age, education, profession, consanguinity with the reference person and sex. We distinguish three levels of education in the model. The first level includes persons with no education, primary school or secondary school education. The second level includes persons with higher non-university education, and the third level consists of persons with university education. The persons in the first education level are used as a reference group.

Five occupation groups are distinguished. The first group comprises unemployed persons. The second group consists of persons earning a wage and the third one of self-employed persons. The fourth group includes retired and pre-retired persons, and the last one non-active persons (students, fund holders and others). The first group is used as a reference group.

Females are used as a reference group for the sex dummy variable.

After the preliminary data analysis, we have identified a number of outliers and deleted them from the sample. These outliers are located mostly in Brussels. Thus, our final sample includes 3343 household members.

Consumption data from the household budget survey has been classified according to the Nace classification. It has been adjusted to match the totals from the Belgian National Accounts. Data on VAT, tax and consumption subsidies and net consumption has been used to construct the consumer price index.

3.3.4. Econometric estimation results

The microsimulation model parameters have been estimated separately for three Belgian regions (Brussels, Flanders and Wallonia). The estimates for most of the model coefficients are in line with common sense (see tables 111-125, section 6.5). While analysing the estimation results one should however keep in mind that a household member can have different occupations during a year.

We start the presentation of the estimation results with the discussion on the estimated coefficients in the wage income equation. The level of coefficient associated with the sex dummy variable demonstrates that men are earning on average more than women and the difference in their earnings is the largest in Wallonia (0.197 for Brussels, 0.33 for Flanders and 0.37 for Wallonia). The estimation results also show that self-employed people and employees earn more than unemployed people, with the exception of Wallonia, where they earn less than unemployed people. We believe that the last result is due to the small sample size. The coefficients corresponding to self-employed status are 1.02, 0.92 and -1.07 for Brussels, Flanders and Wallonia, respectively.

The coefficients corresponding to employee status are 1.33, 1.29 and 2.64 for Brussels, Flanders and Wallonia, respectively. Pre-retired or retired people earn less than unemployed people, with the coefficient corresponding to pre-retired or retired status being -1.6 for Brussels, -1.58 for Flanders and -1.13 for Wallonia. The same results are obtained for non-active people. They earn less income than unemployed people with the exception of Wallonia. However, the coefficient associated with the Walloon region is not significant. The estimator for Brussels is -0.71 and also not significant[8]. The estimator for Flanders is -1.58. The coefficient estimates, associated with education level, are positive for all regions. Age is affecting positively the wage income, while the age squared has a negative effect. The age squared is used to account for the fact that age plays different roles in explaining the income variation for different age groups.

The estimates of coefficients in the capital income equation and in the income equation for self-employed members of the households are similar to the estimates of coefficients in the wage income equation.

On average, capital income of men is higher than that of women. However, the coefficient associated with the sex dummy variable is not significant for Brussels. The coefficients estimates for the sex dummy variable are 0.58 for Flanders and 0.43 for Wallonia.

The coefficients associated with the self-employed status are positive for all regions. They are 2.19 for Brussels, 2.11 for Flanders and 2.54 for Wallonia. The coefficients associated with the employee status and the pre-retired or retired status are positive in all regions, however, they are only significant for Wallonia. Their values for Wallonia are 0.60 for the employee status and 0.63 for the pre-retired or retired status. The coefficients associated with the non-active status are negative and not significant in Flanders and Brussels, however the coefficient is positive and significant in Wallonia. Its value is 0.44. This result can be explained by the presence of fund holders with high capital income in Wallonia.

The coefficients associated with high-school education are positive and significant in all regions except for Wallonia. Their values are 0.09 for Brussels and 0.18 for Flanders. The coefficients

[7] We use 10 % confidence interval for the reference value for acceptance or rejection of nullity hypothesis. Parameters for which there is no indication of their insignificance are significant at 10%. All estimated model coefficients are presented in the appendix.

[8] The P-values associated to these coefficients are 0.55 for Wallonia and 0.21 for Brussels.

associated with university education are positive and significant in all three regions. Their values are 0.43 for Brussels, 0.33 for Flanders and 0.31 for Wallonia.

Age has a positive and significant effect in all regions. The values of coefficients associated with age are 0.18 for Brussels, 0.06 for Flanders and 0.1 for Wallonia. Given the high demand for skilled labour in Brussels, we observe an important role of university education for the level of capital income. The coefficient associated with age squared is negative and significant but its value is close to zero.

The coefficient associated with the sex dummy variable in the pensions equation is positive and significant. Men on average receive more pension funds than women in all three regions. Pre-retired or retired, receive more pension funds than the other occupation categories.

The coefficients associated with the occupation status in the unemployment benefits equation are negative with the exception of pre-retired or retired status. They are also significant. An exception is the coefficient associated with the self-employed status for Flanders. The coefficient associated with pre-retired or retired status is significant for Brussels and Flanders, but insignificant for Wallonia.

The coefficient associated with the sex dummy variable in the other benefits equation is positive and significant only for Flanders. The coefficients associated with pre-retired or retired status are negative and significant for all the regions. The coefficients associated with non-active status are, on the other hand, positive and significant for all the regions. This may be explained by the importance of the household transfers.

3.4. Estimation of the elasticities of substitution

The tasks related to the estimation of the elasticities of substitution between capital and energy on one hand, and between various fuels on the other hand, for all sectors and regions in GreenMod II have been carried out by Francis Altdorfer from ECONOTEC and have consisted off:

- A review of literature on the evaluation of substitution elasticities from bottom-up type models, with particular focus on the treatment of producer behaviour in such models.
- Designing an approach for taking into account producer behaviour in the EPM results, in order to address the issue of the efficiency-gap.
- Designing an approach to address the estimation of interfuel substitution elasticities from EPM.
- Construction of the EPM cost curves corresponding to the sectoral disaggregation level of GreenMod II, for the reference scenario. Preparation of the data for the regression analyses.
- Econometric analyses (formulation of equations, estimation of the substitution elasticities).
- Practical implementation of estimated elasticities in GreenMod II, their testing and validation.

3.4.1. Introduction

The degree of substitution between energy and other types of inputs is of great importance for the evaluation of environmental policies, including the effects of carbon or energy taxes. In case of a computable general equilibrium (CGE) model, such as GreenMod II, the substitution elasticities determine the economic cost of technological adaptation under energy policy constraints.

A criticism of the CGE approach resides in the lack of empirical evidence on such elasticity values. Elasticities of substitution between energy and capital have generally been estimated econometrically from aggregate data or determined by expert judgment. However, this approach has failed to deliver reliable results. The obtained values were diverging and much debate has taken place in the literature on whether capital and energy are substitutable or complementary[9]. Besides, econometric methods fail to capture future technological trends, as they are only based on historical data.

Here, an alternative approach to conventional econometric studies for estimating substitution elasticities used in top-down models is investigated. This approach relies on a bottom-up energy demand model, containing an explicit representation of energy saving technologies and their reduction potentials.

Among the advantages of this approach is the fact that substitution possibilities between capital and energy can vary widely between different sectors, which is consistent with engineering studies on energy conservation potential (Bataille, 1998). While energy and emission forecasting have traditionally relied on top-down modelling, the proposed method is consistent with an increasing trend towards combining top-down and bottom-up approaches to economic modelling.

3.4.2. Objectives

GreenMod II includes nested production functions incorporating substitution possibilities between capital, labour, energy and other inputs, as well as between several categories of energy carriers. The substitution possibilities between production inputs are represented using constant elasticity of substitution (CES) production functions.

EPM is a bottom-up simulation model, projecting energy consumption of exogenous activity variables expressed in physical units and containing a detailed representation of energy consumption and its main determining factors. It also allows the calculation of the cost minimizing energy saving potentials associated with an individual reduction measure in each production sector.

The estimation of GreenMod II model substitution elasticities, presented in this section, is based on the EPM model results.

3.4.3. Literature review

While there is a large and growing literature on the use of CGE models for environmental policy analysis, there is also an increasing tendency to combine top-down with bottom-up approaches, given the limits and the complementarity between the two approaches (indirect, economy wide, effects of top-down models and technology explicitness of bottom-up models). This development is recognised amongst others in IPCC (2001).

One way of combining both approaches is to link the two types of models in a hybrid model, such as in Manne and Wene (1992), Jacobsen (1998), Koopmans and te Velde (2001), Jaccard et al. (2003).

Jaccard et al. (2003) have criticised the lack of behavioural realism of cost minimizing bottom-up models, and built an integrated hybrid model taking into account producer preferences. This approach is based on a discrete technology choice model using a logistic market share function, such as the one usually used in the field of marketing and in the US NEMS energy model (EIA, 2000). A weak point of this approach is the difficulty in finding reliable data for the specific parameters of the model.

Böhringer (1998) describes a different type of hybrid model, namely a CGE model where a specific energy sector or energy intensive activities are represented by bottom-up activity analysis of discrete technology options, instead of the conventional, continuous, CES production functions. In this

[9] More recently, Kuper et al. (2002) found capital-energy elasticities as low as less than 0.001 in absolute value using data on eight Dutch manufacturing industries over the period 1973-1994.

approach, the general equilibrium model is formulated as a Complementarity Problem (CP)[10]. The model used by Böhringer is a simple static one, where only the electricity sector is characterised by discrete technological options.

Frei et al. (2003) have extended this concept to a dynamic formulation, with endogenous investment decision and capital stock evolution, and has presented a simple illustrative application with three production sectors.

This approach seems to be promising for the representation of the technological evolution of a sector such as the electricity production, but it remains at an early stage and does not seem suitable to cope with many energy saving technologies at detailed sectoral disaggregation that we are trying to take into account.

It should be noted that while the motivation of Jaccard et al. (2003) is mainly to model long term endogenous technological changes and effects of technology specific policies, the aim of our research is different. Its aim is to estimate elasticity values for a short to medium term timescale on the basis of the bottom-up engineering-type energy saving potentials.

A few examples can be found, where the elasticities of substitution have been estimated from the bottom-up cost curves. Müller (2000) describes a theoretical framework to reconcile engineering and economic approaches to energy and investment demand. It is a putty-clay[11] model, where the capital is not homogeneous and characterised by its energy efficiency, and where the cost of new capital is a function of its energy efficiency. The investment decision therefore involves not only the choice of production capacity, but also the choice of the capital equipment's energy efficiency.

Müller (2000) uses the fact that the K-E (capital-energy) isoquant is a mirror image of the Total Cost of Conservation (TCC) curve, as described by Stoft (1995), and estimates from bottom-up data of a conservation supply curve the parameters of a CES production function linking the specific capital cost to the specific energy consumption.

Dellink et al. (2004) point out the complexity of using discrete technology modelling, given the large number of technological options available for pollution reduction. They propose a methodology combining dynamic CGE models with the information on pollution abatement technologies included in a bottom-up approach. Expenditures on abatement are explicitly specified to capture as much information as possible about the technical measures, organised into the abatement cost curves. These measures, translated into a pollution abatement substitution (PAS) curve are approximated by a CES curve.

For the estimation of capital-energy elasticities, the approach we have followed is analogous to those of both Müller (2000) and Dellink et al. (2004).

3.4.4. The EPM model

The EPM model, which includes techno-economic data based on energy consumption and emissions reduction measures, allows in particular:

- to construct the reference scenarios (business as usual), representing the expected future evolution in the absence of any new emission reduction policy;
- to evaluate cost effective emission reduction potentials;
- to construct emission reduction scenarios, based on the reduction measures with the marginal costs below a given ceiling;

[10] The Complementarity Format keeps the general equilibrium conditions in their most general form, admitting weak inequalities (≤), which is not permitted by standard numerical calculation methods.

11 Meaning allowing ex ante, but no ex post, substitutions between capital and energy.

- to construct cost curves, providing either the marginal or the total costs as a function of the level of emissions or energy consumption reduction.

Particular advantages of EPM for our research aim include:

- a detailed sectoral disaggregation for the calculation of energy consumptions (e.g. 10 subsectors for the iron and steel industry), which allows to take into account intra-sectoral structural effects;
- the evaluation of cost-effective energy saving potentials associated with the individual reduction measures in each sub-sector;
- use of a techno-economic database based on over 10 years experience in many site specific and macro-level studies on energy saving potentials.

EPM does not explicitly model output effects, but it can be used to analyze the substitution effects of factor price changes derived from its techno-economic information on energy saving potentials, such as cost curves. The scope of our research is thus limited by the kind of data that can be extracted from the EPM model. The present research has been focused mainly on capital-energy substitution in the final energy consumption by the industry.

3.4.5. Mathematical formulation

The sectors for which a reduction potential is estimated in EPM belong to the group of GreenMod production sectors for which part of the nested production function is the following CES function:

$$KE = a[\gamma \cdot E^{(\sigma-1)/\sigma} + (1-\gamma) \cdot K^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)} \quad (45)$$

where KE is the capital-energy bundle, K is the stock of capital and E is the total energy consumption[12], both expressed in monetary units.

This function can also be written as:

$$(KE/a)^{-\rho} = \gamma \cdot E^{-\rho} + (1-\gamma) \cdot K^{-\rho} \quad (46)$$

where :

$$\rho = (1-\sigma)/\sigma$$

For a given value of KE, the marginal rate of substitution between K and E is:

$$-\partial K/\partial E = \gamma/(1-\gamma) \cdot (K/E)^{1/\sigma} \quad (47)$$

This expression can be rewritten as:

$$K/E = [(1-\gamma)/\gamma]^{\sigma} \cdot (-\partial K/\partial E)^{\sigma} \quad (48)$$

or

$$ln(K/E) = ln(c) + \sigma \cdot ln(-\partial K/\partial E) \quad (49)$$

where $c = [(1-\gamma)/\gamma]^{\sigma}$.

σ can thus be estimated by linear regression, provided statistical data are available for K, E and $\partial K/\partial E$.

The available data consists of a set of bottom-up data on a package of reduction measures, which are ranked by cost-effectiveness. The regression analysis differs from traditional time-series or cross-

[12] Note that E is a fuel-electricity bundle.

section analyses in that the statistical population is the set of measures, and the reduction potentials are evaluated ceteris paribus, which simplifies the econometric estimation procedure.

It can be derived that:

$$\gamma = 1/(1 + c^{1/\sigma}) \quad (50)$$

It is assumed that the substitution between K and E corresponds to the investments in energy saving measures of EPM according to the reference scenario (the business as usual (BAU) scenario, in which an exogenous level of technological progress is assumed for each sector).

In theory, this is an approximation, since it neglects the existence of structural shifts towards less energy intensive activities that could take place within each sector as a result of increasing energy costs. However, in practice many energy audits carried out on industrial sites in the last few years have shown that on a 10-year time horizon the energy saving potentials lie in energy saving measures rather than in such structural shifts.

Hence the CES production function is obtained from an EPM cost curve, which is a discrete function, and represents the reduction cost as a function of the energy saving.

For each measure m, the contributions ΔK_m and ΔE_m are calculated as follows:

$$\Delta K_m = C_m \cdot R\,d_m \quad (51)$$

$$\Delta E_m = P_m \cdot R\,d_m \quad (52)$$

where C_m is the unit investment cost of measure m, measured in €/(GJ/an); $R\,d_m$ is the energy saving of measure m, measured in TJ; P_m is the unit price of the energy carrier saved by measure m, measured in €/GJ.

Let's assume that the measures are ranked according to an increase in the value of the C_m / P_m ratio. K and E can be expressed as:

$$K = K_0 + \sum_m \Delta K_m \quad (53)$$

$$E = E_0 + \sum_m \Delta E_m \quad (54)$$

where K_0 and E_0 correspond to the reference scenario, and $\sum_m \Delta K_m$ and $\sum_m \Delta E_m$ correspond to the EPM reduction potential from the reference scenario. K_0 is supplied by GreenMod II, whereas E_0, $\sum_m \Delta K_m$ and $\sum_m \Delta E_m$ are calculated from the EPM model.

The marginal rate of substitution can be approximated by:

$$-\partial K / \partial E = \Delta K_m / \Delta E_m = C_m \cdot Rd_m / (P_m \cdot Rd_m) = C_m / P_m \quad (55)$$

where m is the marginal measure.

At this stage, the values of K, E and $\partial K / \partial E$ are available, allowing the econometric estimation of the elasticity of substitution. As the (K, E) function is discrete, the observations used in the econometric estimation are chosen in the middle of each segment.

In CGE models like GreenMod II, elasticities of substitution represent reduction potentials that are effectively implemented by the economic agents, while the EPM reduction potentials are techno-economic potentials, which are not necessarily exploited. The difference between the two values corresponds to what is commonly called the 'efficiency gap' (Koopmans and te Velde, 2001).

Ample evidence of this efficiency gap is given in the scientific literature, for many countries (Brown, 2001). ECONOTEC's experience with energy audits of industrial production sites confirms this observation. For example, among a sample of 309 electricity saving measures identified in 21 production sites of a variety of industrial branches in Wallonia, 52% had a payback period of less than 2 years and represented two thirds of the saving potential (ECONOTEC, 2002). Another evidence of the efficiency gap can be found in the high implicit discount rates (which can exceed 100%) used by producers in their decisions about energy saving investments (Train, 1985; DeCanio and Laitner, 1997).

In the literature, many reasons are given for explaining the existence of this efficiency gap. These reasons are grouped into different categories of obstacles, such as:

- market failures (principal agent problem, lack of information due to the public good character of this information) ;
- non-market failures (high discount rate due to the size of the perceived risk of investments that are outside of the core business of the company, transaction costs etc.) ;
- psycho-sociological factors (nature of the decision making process in companies etc.).

The payback time required for energy saving investments is generally much shorter than for investments in the core business of a company, among other reasons because of the uncertainty in future energy prices.

Because of the efficiency gap, actual behaviour of the firms do not correspond to a cost minimisation on the basis of the bottom-up EPM cost data and the cost of capital data from GreenMod. While in GreenMod the rate of return to capital is in the order of 10%, the implicit discount rate in the decision making of firms is much higher, as is witnessed by the short payback periods[13] (less than 2 years) generally required by industrial companies for energy saving investments[14].

A way of addressing this issue is to take into account that this gap arises because of "hidden" or "intangible" costs, i.e. costs that are not taken into account in the conventional bottom-up cost data for energy saving technologies. It could also be envisaged that the use of higher discount rates, corresponds to the implicit discount rate of the producers (Train, 1985; Jaccard, 2003). Such approach allows to keep the basic assumption of rational (cost minimising, utility maximising) consumer and producer behaviour underlying the economic theory on which the GreenMod model is based.

In the literature on bottom-up and top-down combinations, the efficiency gap issue has been addressed by various types of adjustments. Müller (2000) takes into account the principal agent problem by multiplying the price of energy in the objective function by a factor comprised between 0 and 1. He also takes into account the non market failures by adding adjustment costs. Koopmans and te Velde (2001) assume that some of the bottom up data they use has neglected costs. They further use a partial adjustment process to take into account that in practice not all profitable investments are undertaken. This adjustment process consists of increasing the discount rate until the efficiency improvement predicted by their model becomes more realistic.

In order to keep the consistency between the top-down and bottom-up approaches, given the lack of quantitative information on the 'hidden costs', we have made a simple assumption, that the efficiency gap can be represented by multiplying the reduction costs by a given correction factor.

The value of this sector specific correction factor is equal to the ratio between the slope of the cost curve's tangent at the initial point (E_0, K_0) (this slope is taken from the estimated K-E relationship) and the slope of the isocost line in the K-E space, $-1/(RK \cdot (1+tkf)+d)$, where RK is the annual

[13] Shorter than for investments in the core business of the company, for a variety of reasons (uncertainty on future energy price etc.).

[14] If the lifetime of equipment is 10 years, for the payback time to be less than 2 years, the equivalent annual rate of return must exceed 50%; for a 1 year payback time, it must be at least 100%.

(net) rate of return to capital, tkf is the income tax rate (expressed as a fraction of the net income) and d is the depreciation rate. This is illustrated graphically in the Fig. 3.9 below. This approach allows for the reference point to be cost optimum, which is a necessary condition in the CGE modelling.

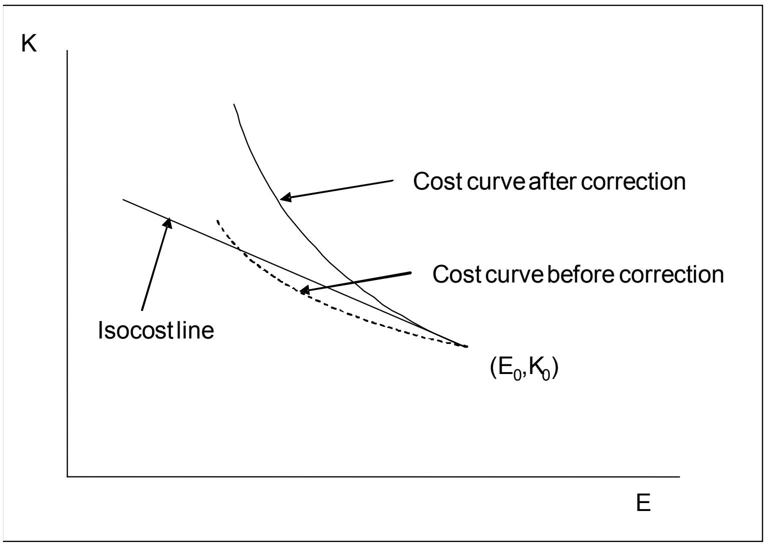

Fig. 3.9. The isocost curve

The elasticities are then calculated as follows for each sector:

- estimation of the (CES) cost curve before correction, and calculation of the slope at the reference point (E_0, K_0);
- calculation of the slope of the isocost line and the correction factor;
- estimation of the elasticity of the cost curve after correction.

The production functions in GreenMod II comprise two distinct CES functions, representing the substitution between electricity and the 'non-electric energy inputs' bundle (which we will refer to as 'fuels') and between individual fuels.

In EPM, energy saving measures are defined over two categories of energy carriers: fuels and electricity. There is no distinction between individual energy carriers in the EPM model, and hence there are no data for estimating the inter-fuel substitution elasticities. Therefore we only estimate the substitution between fuels and electricity.

Energy saving potentials in EPM are represented as functions of the level of investment, both in case of fuels and in case of electricity. These potentials implicitly represent possibilities of substitution between fuels and electricity. For a given expenditure level, a producer can choose to reduce either the fuel consumption or the electricity consumption.

However, the relationship remains indirect, since EPM contains no technology substituting directly electricity for fuels or vice versa. Therefore, the analysis of substitution between fuels and electricity performed with the use of EPM should be considered with caution.

The fuel-electricity substitution elasticity represents the relationship between the fuel consumption E_{fuel} and the electricity consumption E_{el}, for a given value of the total energy consumption E.

For a given value of K, E_{fuel} is a function of E_{el}, which can be approximated by a CES function. Such a relationship has been constructed numerically as an approximation of the discrete function, by choosing combinations of E_{comb} and E_{el} that keep K as close as possible to constant .

In principle, a substitution curve could be obtained for each level of K. However, in practice, the number of observation points that can be obtained is small and in order to increase this number, K should be chosen at an intermediate value. The elasticity of substitution is then estimated in the same way as the K-E substitution elasticity.

3.4.6. Results

The elasticities of substitution between capital and energy have been estimated at the sectoral aggregation level of GreenMod for all industrial branches represented in EPM (this excludes the very minor fraction of energy consumption of 'other industries', for which the data is not deemed reliable enough). It should be noted that, in EPM, sectors secE23 to secE29 of GreenMod (which are relatively less energy intensive) are aggregated into a single sector (manufacturing of metal products). For these sectors the elasticity has been assumed to be the same and equal to that of the single sector in EPM.

Elasticities have also been estimated for the various branches of the tertiary sector, using the same methodology, but numerical results prove to be much too low and will not be given here. The reason for this is that, for this sector, the energy saving potential in EPM is still underestimated, because of a lack of data on the potential of branch specific measures. It should be noted that the residential and the transportation sectors have not been addressed, the former because in GreenMod no elasticities of substitution are used for this sector, the latter because the savings potential for this sector is not represented in EPM.

The elasticities have been calculated from energy saving cost curves for the year 2010, using 2000 as a base year, which corresponds to a timeframe of 10 years. The data used are those for Wallonia, which is the most energy intensive region and the best represented region in EPM. As the analysis is carried out by sector, it was assumed that the results can be applicable to the other regions of Belgium as well. The main differences between Belgian regions are indeed taken up by the level of penetration of each sector depending upon the region of its location.

Industrial branches considered in our research correspond to 12 sectors in GreenMod and 62 sub-sectors in EPM.

These sectors include mostly energy intensive sectors, within which the saving potentials mainly apply to heavy, energy intensive processes. Such processes have long lifetimes and their production capacity is not expected to grow much. The expected savings therefore essentially take place on the existing production equipment. The used cost curves correspond to the total capital and the total energy consumption in 2010.

The results are summarised in Table 3.2 and presented graphically in Fig.3.10-3.15.

Table 3.2 Capital-energy elasticities of substitution

GreenMod sector	Name of GreenMod sector	Elasticity before correction factor	Elasticity after correction	Adjusted R2
secE10	Manufacture of food products and beverages	0.12	0.15	0.95
secE16	Manufacture of pulp, paper and paper products	0.10	0.19	0.93

secE19	Manufacture of chemicals and chemical products	0.06	0.10	0.93
secE21	Manufacture of other non -metallic mineral products	0.07	0.18	0.98
secE22	Manufacture of basic metals	0.19	0.40	0.82
secE23	Manufacture of fabricated metal products	0.10	0.11	0.94
secE24	Manufacture of machinery and equipment n.e.c.	0.10	0.11	0.94
secE25	Manufacture of office machinery and computers	0.10	0.11	0.94
secE26	Manufacture of electrical machinery and apparatus n.e.c.	0.10	0.11	0.94
secE27	Manufacture of radio, television and communication equipment and apparatus	0.10	0.11	0.94
secE28	Manufacture of medical, precision and optical instruments, watches and clocks	0.10	0.11	0.94
secE29	Manufacture of motor vehicles, trailers and semi-trailers	0.10	0.11	0.94

The estimated elasticity values lie in the range traditionally found in the literature (Bataille, 1998) and vary substantially between the sectors. The estimated elasticity is highest in the iron and steel sector and lowest in the chemical and metal products sectors. This result is explained by technological considerations and, in particular, by the possibility in the iron and steel sector to adopt the strip casting technology.

The application of the correction factor increases the values of elasticities. The relative increase is much larger for the most energy intensive sectors. For these sectors the investment in energy saving measures is a larger fraction of the total capital, than for the other sectors.

The value of correction factor lies between 3.7 and 5.5 depending upon the sector. The high value of the correction factor partly reflects the size of the efficiency gap, but can also be ascribed to other factors such as:

- the fact that the lifetime of reduction measures is often lower than the average lifetime of the capital stock (typically a factor of 2, but it depends on the technology) used in CGE models such as GreenMod under the assumption of homogeneity of the capital stock. This tends to underestimate the capital cost of the reduction measures (which in reality tend to require a more frequent replacement);
- the fact that labour costs (for the operation and maintenance) are not taken into account while estimating the substitution possibilities between energy and investment; labour costs are actually attributed to the different nest of the production function. Thus some costs (such as labour costs) seem to be underestimated in practice, as recent re-assessments show.

In summary, the approach used in our research for estimation of substitution elasticities has the following advantages:

- it remains consistent with the modelling framework and assumptions of GreenMod II (rational producer behaviour, use of CES production functions, nesting);
- the efficiency gap is taken into account;
- the elasticity values are in the order of magnitudes found in the literature, but they differ significantly across sectors;
- elasticity values are estimated based on the engineering data identifying individual energy saving technologies.

It should be noted that, the energy saving potentials of EPM are rather conservative, and tend to underestimate the real potentials for energy saving, because they are limited to known proven and currently commercially available technologies and solutions.

Elasticities are likely to change with the technological evolution, and to increase in the long run, where new technologies and technical progress will increase savings potentials and reduce costs. In EPM, the energy savings are evaluated for the year 2010 and don't include the replacement of all existing energy intensive equipments. There also remains a significant uncertainty related to the data on capital stock used for the estimations.

In GreenMod, each sector incorporates energy consumption and capital stock, related to the sector's transportation activities, while in EPM, the energy consumption of all transportation activities is considered in a separate sector. However, the impact of these differences between the two models upon the estimated elasticities should be rather small in energy intensive sectors[15].

It should also be noted that the cogeneration[16] technologies have not been included in the assessment process; they are more complex to handle and in fact it is quite difficult to ascribe them to a particular sector, because they are often subject to partnerships with the electric utilities.

[15] Note that the share of vehicles in the total capital stock of a sector is also a source of heterogeneity, as vehicles have a smaller lifetime than other capital equipment, such as buildings.
16 Cogeneration of heat and power.

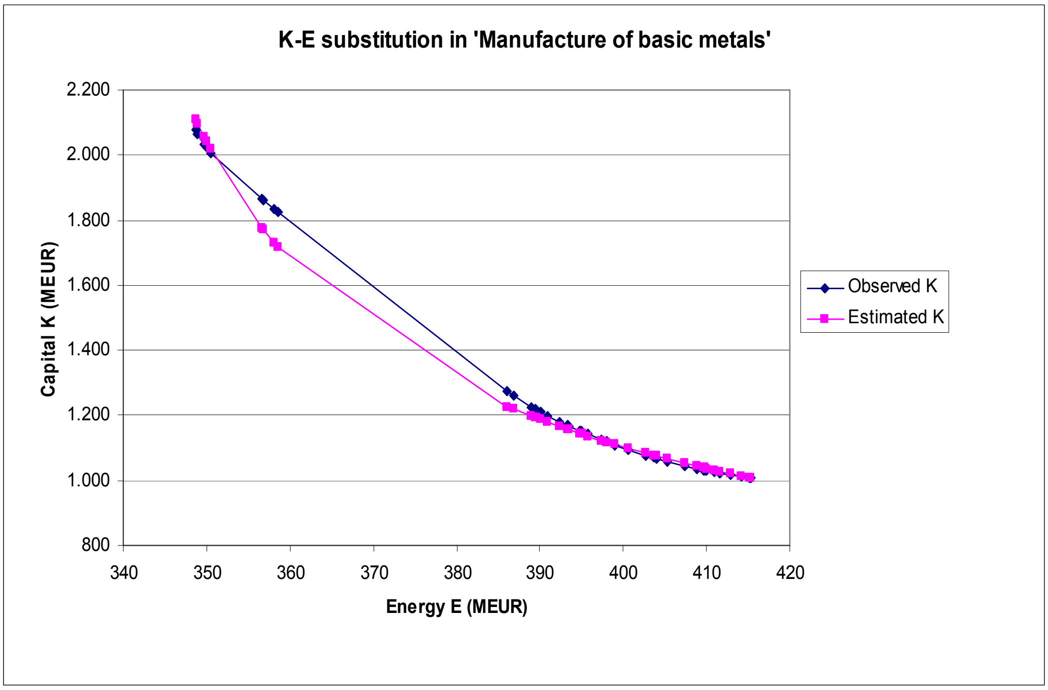

Fig. 3.10. Capital-energy substitution in manufacture of basic metals

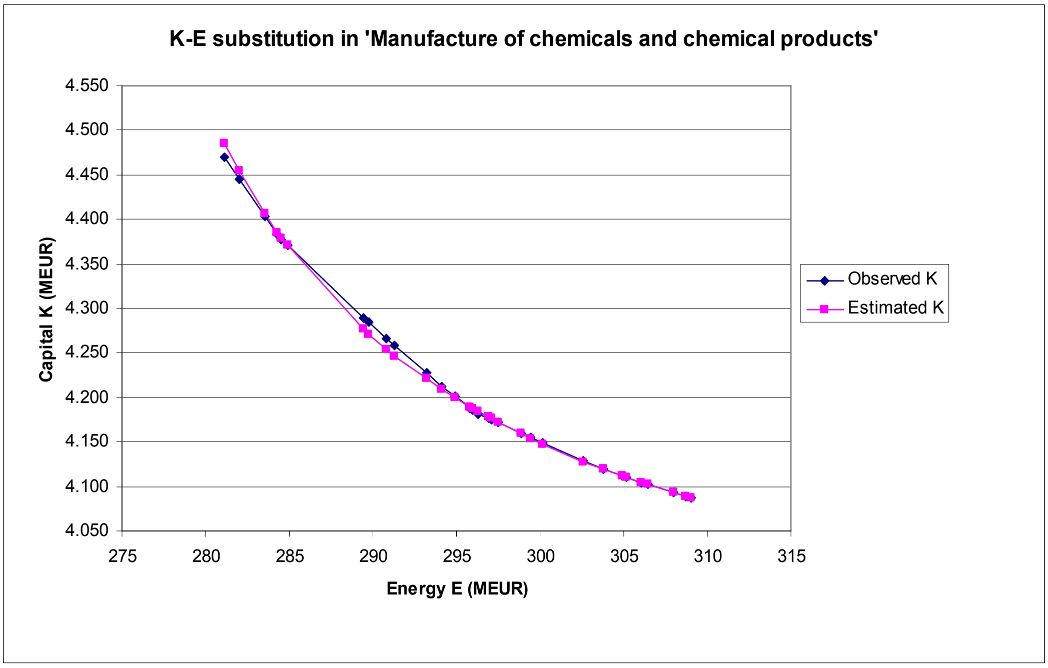

Fig. 3.11. Capital-energy substitution in manufacture of chemicals and chemical products

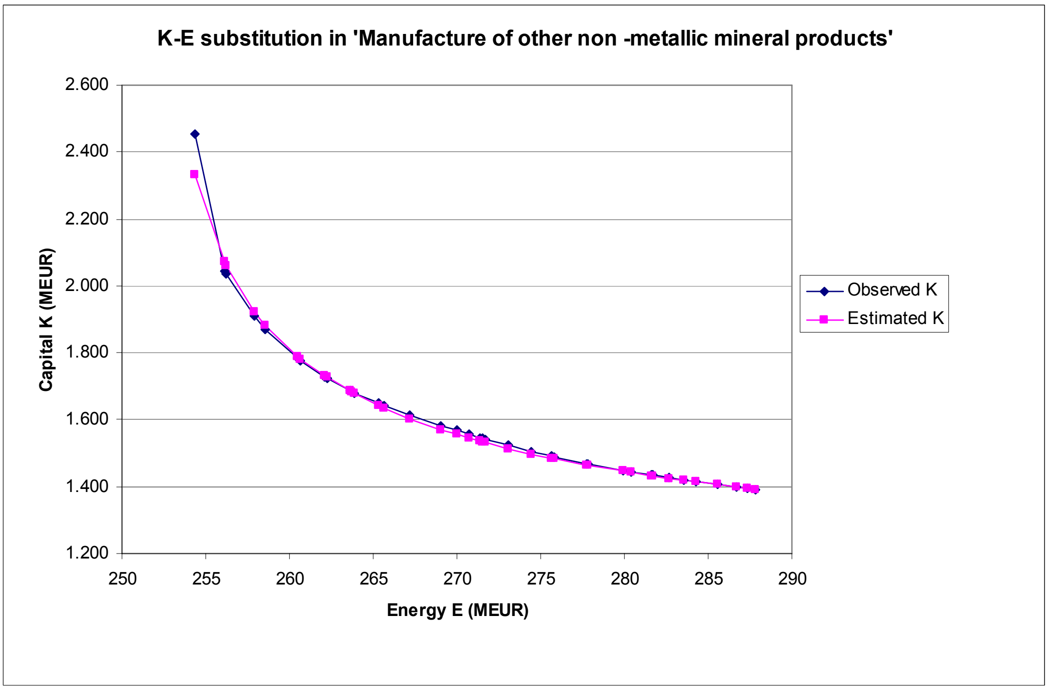

Fig. 3.12. Capital-energy substitution in manufacture of other non-metallic mineral products

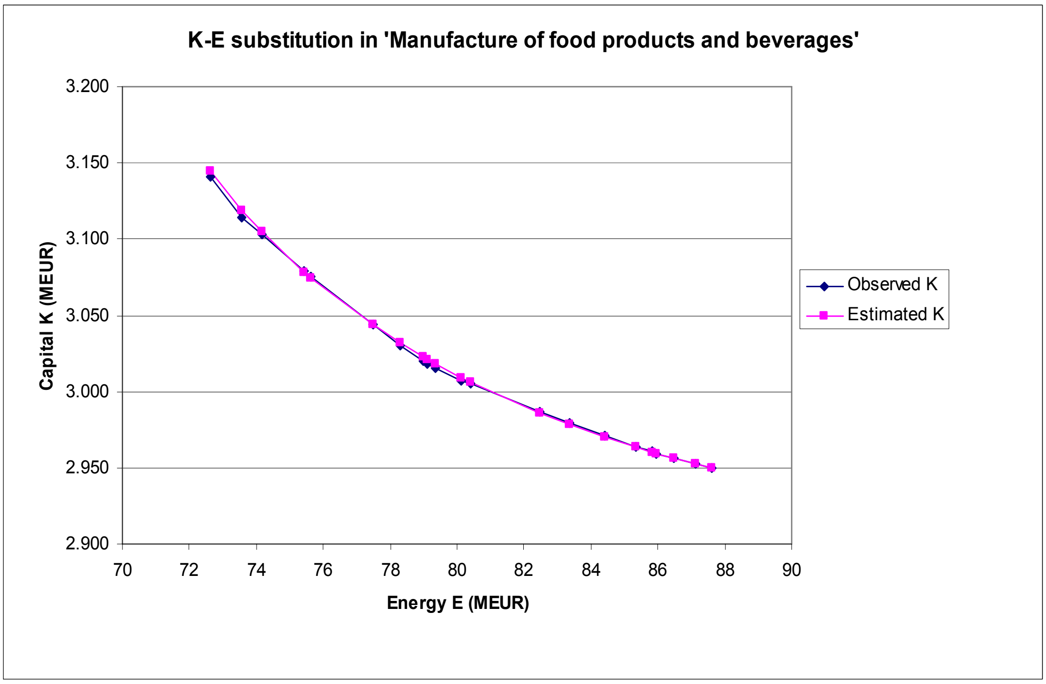

Fig. 3.13. Capital-energy substitution in manufacture of food products and beverages

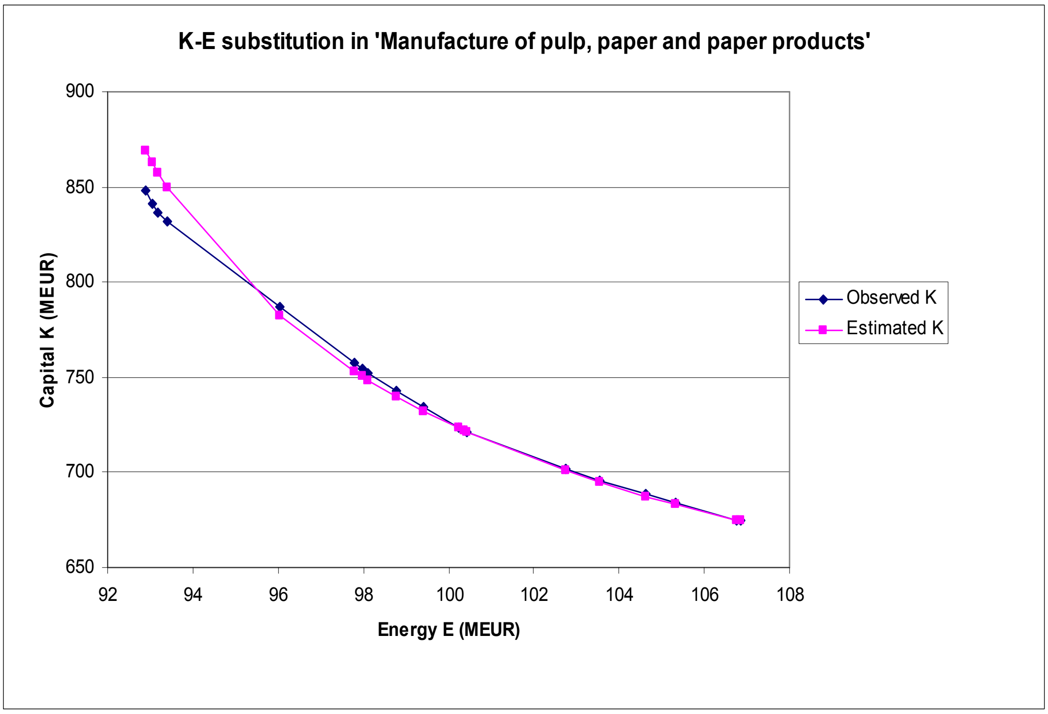

Fig. 3.14. Capital-energy substitution in manufacture of pulp, paper and paper products

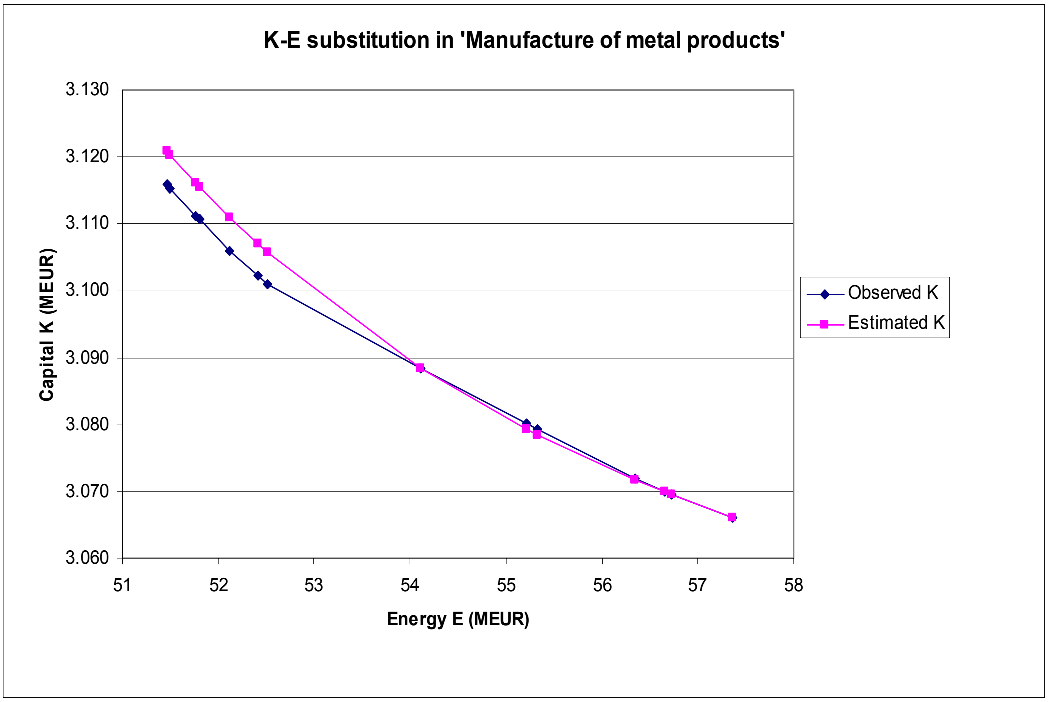

Fig. 3.15. Capital-energy substitution in manufacture of metal products

3.5. Modelling of the dynamic permit markets

The tasks in this project related to the modelling and analysis of tradable pollution permits were carried out by Dr. Marc Germain, from the Center for Operations Research and Econometrics (CORE) of the Catholic University of Louvain and consisted of:

- Survey and synthesis of the literature in the following fields: design and properties of tradable permits markets in a dynamic context and environmental issues, including the issue of banking and/or borrowing of permits in an OLG framework.
- Simulations of different scenarios of environmental policy, with the objective of paving the way for the extension of the GreenMod II model by qualifying the policy impacts on the involved actors , in particular sectors and regions and of alternative permits allocation rules such as egalitarian, grandfathering, ability-to-pay, etc.

3.5.1. Review of literature

The literature on the issue of whether banking and/or borrowing of permits should be recommended or not does not answer this question in a univocal manner. The recommendations of the authors depend on the assumptions of their models. The results depend in particular upon whether pollution accumulates or not, whether the context is deterministic or includes uncertainty, whether the permits market is competitive or not, etc.

In a deterministic framework (which characterizes the GreenMod model within the present project), the main result is that banking/borrowing of permits is suboptimal from a social point of view. The problem of such framework is that permits prices may be different from the marginal damage because of the arbitrage between permits of different periods. This problem can nevertheless be overcome by fixing an exchange rate between permits of different periods to be different from one. For example, if firms tend to bank too much, the idea is to lower the value of current permits in terms of future permits such that to discourage banking.

For the survey of literature on environmental issues and emission permits in an OLG framework see Germain and Lambrecht (2005).

3.5.2. Static model

The burden sharing of pollution abatement costs, e.g. in the Kyoto Protocol context, raises the issue of how to share these costs between different entities, such as countries, regions or industries, and how the pollution permits should be distributed between the parties involved in the Protocol. In Belgium, the debate arises concerning the burden sharing between Flanders and Wallonia. The Walloon region includes more energy intensive industries compared to the Flemish region. Hence, from the point of view of Flanders, the bulk of the effort on energy saving should be made in Wallonia, where the abatement measures are assumed to be less expensive. On the contrary, this solution is considered to be too costly by Wallonia.

In the context of Belgian burden sharing debate, it is important to emphasize the fact that energy intensive production activities are not necessarily the most inefficient ones. Differences in energy consumption between the Belgian regions can be explained by differences in their production patterns. For example, Wallonia is specialized in the production of relatively energy intensive goods, which leads to its high energy consumption. Given such differences in the production patterns of the Belgian regions, there is a clear scope for national and international emissions permits trade, which can be beneficial to all parties involved.

In order to analyse the issue of burden sharing of abatement costs between the Belgian regions, three theoretical models of a small open 2 regions – 2 sectors economy have been built, including a static model used for short term analysis, and two dynamic models, which take into account endogenous specialisation, capital accumulation and growth. The dynamic models have been used for long-term analysis. For the full description of the static model see Germain et al. (2003).

The static model incorporates the representation of two regions, two sectors and three inputs. Each sector produces one good by using energy and a sector specific production factor (F for sector 1 and G for sector 2). F and G are the aggregates of factors of production other than fossil energy (such as capital, labour, infrastructure etc.). These specific factors are not mobile between the regions. Regions are endowed with a specific amount of F and G and share the same technologies. Regions produce and trade good 1 and good 2 produced by sector 1 and sector 2, respectively. Given the assumption of a small open economy, firms are price-takers on the world market, so that the prices of their output are equal to the international prices, which are exogenously given in the model. The prices of sector specific factors F and G are endogenously determined in the model according to the market clearing conditions.

The amount of polluting emissions is proportional to the amount of energy consumed by the production sectors. The economy is also characterised by the following three assumptions. First, sector 1 is assumed to be more energy intensive (and thus more pollution intensive) than the other sector. In other words, the quantity of energy (and emissions) used per unit of output in sector 1 is higher than in sector 2. Second, one of the regions is assumed to have a higher endowment of input factor F. Third, the elasticity of energy intensity (defined as the energy used per unit of the specific input factor) with respect to the price of energy is assumed to be higher for sector 1 than for sector 2.

Because one of the regions has a higher endowment of production factor F, associated with the sector 1, this region is specialised in the production of good 1. Given that good 1 is more energy intensive than good 2, the energy consumed per unit of Gross Regional Product (GRP) is higher for the region with higher endowment of the production factor F. For a given increase in the price of energy, the relative decrease in the energy consumption is larger in sector 1. Hence, the relative decrease in the regional energy consumption is larger for the region specialised in production of energy intensive good 1.

Given the national objective of emission reduction (as imposed for example by the Kyoto Protocol), three different burden sharing scenarios are considered. These scenarios are first considered in a national framework (i.e. in the absence of an international market of tradable permits), where the emissions reduction is achieved through an increase in the tax on energy use. The proportional reduction scenario (P) specifies identical reduction in the regional energy consumption (or equivalently in the regional emissions). Under the optimal scenario (O), abatement measures are implemented at the national level so that total abatement costs are minimised and each region bares alone the share of the effort specified by the national objective. Finally, the egalitarian scenario (E) keeps the efficiency property of the optimal scenario, but defines an interregional transfer so that the relative losses of welfare are identical between regions.

It may be shown that the two first scenarios are unfavourable for the region specialised in the production of energy intensive good 1, since the relative decrease in the GRP due to the emissions reduction is higher in this region. In case of the proportional reduction scenario (P) this result follows from the fact that the relative decrease in the GRP is proportional to the energy intensity of the GRP, which is higher for the region specialised in energy intensive good 1. This is also true for the optimal scenario (O). Under the egalitarian scenario (E), the relative decrease in the GRP is proportional to the relative decrease in the regional energy consumption, which is larger for the region specialised in energy intensive good 1. This observation explains the fact that the optimal scenario (O) is more unfavourable for the region specialized in energy intensive good 1 than the proportional reduction scenario (P). On the contrary, the region specialized in energy extensive good 2 is better off under the optimal scenario (O).

Contrary to the optimal scenario (O), the proportional reduction scenario (P) is inefficient because the increase in the tax on energy use is different in the two regions. This means that the marginal abatement costs are not equalised between the production sectors in the two regions. The egalitarian scenario (E) is efficient by its construction design and implies that a relative decrease in the GRP is equal between the two regions, due to the compensating transfer from the less affected region to the more affected one.

Similar conclusions can be derived in the framework of an international market of tradable permits. The design of such market is similar to the one recently implemented at the European level for the CO2 emissions of certain energy intensive industries. In case of the international framework, welfare estimations for the three scenarios are expressed in terms of reduction in the endowments of emissions permits instead of emission reductions.

Welfare results of the three scenarios, calculated using national and international frameworks, have the same "price" effect on the GRPs channelled through the increase the permits price but differ in terms of the "endowment" effect that is in terms of the quotas attributed to the regions. One observes in particular that an identical decrease in the regional endowments of permits does not lead to an identical decrease in the welfare under these two frameworks. This highlights the possible bias of an environmental policy based exclusively on a burden sharing criteria expressed in terms of quotas of pollution permits.

Given the results of the static model one may conclude that in case of Belgium Wallonia will be better off under the proportional reduction scenario (P) and worse off under the optimal scenario (O).

3.5.3. Dynamic models

In order to analyse the long-run effects of burden sharing and emissions permits trade, we developed two dynamic 2 sectors – 2 regions – 2 inputs (capital and energy) Heckscher-Ohlin models of a small open economy with an international tradable permits market.

The following assumptions are used in both models. Factors of production include capital and fossil energy. Regional factor endowments are endogenous. Sector 1 produces capital goods while sector 2 produces consumer goods. Energy is imported and emissions are proportional to the energy use. Sector 1 is more energy intensive than sector 2. The technologies of the sectors are the same in both regions. Because the country is treated as a small open economy, prices are exogenously determined by the rest of the world. One of the two regions is specialised in the production of an energy intensive good. The models incorporate the representation of decreasing returns to scale at the firm level and constant or increasing returns to scale at the sectoral level. They also incorporate the representation of endogenous economic growth.

The two dynamic models differ in their time horizon and in the way endogenous growth is modelled. The first dynamic model is a two-period model, where the aggregate productivity of a firm depends on the capital accumulated at the level of its sector and region. Depending on the initial region specific sectoral capital endowments, specialisations of the two regions will either converge or diverge through time.

While considering the impact of environmental policy on the sectors with respect to the baseline scenario, one expects that the relative loss in profits for the energy intensive sector 1 is larger than for the energy extensive sector 2. This is precisely what happens in the static framework described in the previous paragraph and it is also the case for the dynamic model under consideration. Each period of time the relative loss in profits for the energy intensive sector is larger than the relative loss for the energy extensive sector. However, the model also shows that under certain economic conditions described by the evolution of the permits price and by the initial capital endowments of the sectors, the relative loss of the energy intensive sector in terms of the total actualised profits is smaller than the same loss for the energy extensive sector. It is interesting to note that this non-intuitive result can occur in case when regional specialisations diverge with time or in case when the energy intensive sector is associated with the largest total loss in profits per period.

The results of the first dynamic model demonstrate that the relative decrease in profits in both sectors is larger in the second period than in the first one. In both periods, profits are directly affected by the increase in the energy price (through the permits price). In the second period, profits are indirectly and negatively affected by the decrease in the factors' productivity[17]. In case of increasing returns to scale at the sectoral level, this indirect effect explains why the loss in profits is larger in the second period.

The second dynamic model has been developed in collaboration with Prof. Raouf Boucekkine, a leading expert in growth theory at the University of Louvain (Germain and Boucekkine, 2005). It is a T-period endogenous growth model, where the aggregate productivity of a firm depends on the capital accumulated at the level of its sector and region. At the sectoral level there exist technological spillovers between the regions. Because of the existence of these interregional spillovers, sectoral production technology is characterised by constant returns to scale. The respective specialisation of the two regions converges through time, but not necessarily in a monotonous way.

The second endogenous growth model has been used in order to analyse the dynamical sharing rules of emissions permits market. Following Böhringer and Lange (2003), the permits endowment of a firm is represented as a function of its past emissions or production.

In order to analyse the impact of the environmental policy upon the sectoral performance we have considered the following economic variables: sectors' capital stock, value added and total revenues after transfers (i.e. taking into account the endowments of emissions permits).

According to the model results, the level of the capital stock in a certain sector is affected equally, irrespective of its regional location. This follows from the fact that regions face the same exogenous prices of their outputs and share the same technologies. Given an "emission-based grand-fathering" sharing rule, the energy intensive sector is more negatively affected by the environmental policy than the energy extensive sector. This result does not necessarily extend to the situation with a "production-based grand-fathering" sharing rule.

The overall impact of the environmental policy on the level of sectoral value added depends upon the "capital effect" described above and the effect of an increase in the total energy costs. The effect of an increase in the total energy costs benefits the energy intensive sector because its elasticity of energy consumption is higher than the one of the energy extensive sector. Thus the direction of the overall impact of the environmental policy on the level of sectoral value added is ambiguous and depends upon the interplay between the "capital effect" and the effect of an increase in the total energy costs. In case of an "emission-based" sharing rule, the "capital effect" prevails if sectoral returns to scale are close to 1 or when the share of energy inputs in production is low.

The total sectoral revenues are defined as the sectoral value added plus the net transfer received by the sector. This net transfer is equal to the endowment of permits received less the permits used, multiplied by the price of permits. The analysis with the model is limited to an "emission-based" allocation rule, where the endowment of permits received is proportional to the energy consumption of the previous period. The following two cases are considered: the case when a firm explicitly takes into account the existence of an "emission-based" allocation rule and the case when it does not explicitly take it into account. Under the assumption that the baseline is characterised by the convergence of sectoral growth rates and given that the proportion between the permits endowment and the energy consumption is the same for the two sectors, the environmental policy implementation leads to larger profit loss for the energy intensive sector than for the energy extensive one.

[17] The productivity of factors declines due to the decrease of the capital stock inherited from the previous period. The decline of the capital stock is a consequence of the increase in the price of energy in the first period.

At the last stage of the analysis we evaluate the impact of the environmental policy at the regional level. This impact depends on the specialisation of the region along the baseline. The two regions converge to the same specialisation (measured by the ratio of the capital stocks of their respective sectors), but not necessarily in a monotonous way. The levels of initial capital endowments and technological spillovers, under which the spread of specialisation is reversed have been derived. In case when the profits loss is larger for the energy intensive sector, the region specialised in production of the energy intensive good suffers more from the implementation of the environmental policy[18].

3.6. User-friendly interface for GreenMod II

A user-friendly interface has been adapted from the EcoMod Model Management software for an aggregate version of GreenMod II model with oligopolistic competition and increasing returns to scale. The interface enables the users to run policy scenarios.

A user manual for the interface is available in the appendix 2.

[18] This is true whether the analysis is made using the level of the value added or the level of the revenues with transfers as the welfare measure.

4. Simulation and results

In this section we evaluate the national, regional and sectoral effects of five policy scenarios aiming at CO2 abatement, using the GreenMod model:

- A tax of 10€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)
- A tax of 20€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)
- A tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households
- A tax of 20€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households
- The compliance with the voluntary agreements undertaken in Wallonia and Flanders

The results of the policy measures are evaluated with regard to the baseline scenario. All results, if not indicated otherwise, correspond to year 2012[19].

The baseline scenario (BAU)

The medium term hypotheses concerning the baseline scenario are based on projections from the OECD, the European Commission, the International Energy Agency and the Federal Planning Bureau of Belgium.

Regional population growth is an important determinant of the size and pattern of energy demand. The baseline scenario also takes into account the demographic trends at the regional level (see table 4.1).

Table 4.1. Assumptions regarding the population growth rates by region

	2005	2006	2007	2008	2009	2010	2011	2012
Belgium	0.22%	0.21%	0.20%	0.20%	0.19%	0.19%	0.18%	0.18%
Brussels	0.22%	0.23%	0.25%	0.26%	0.27%	0.28%	0.30%	0.30%
Flanders	0.19%	0.17%	0.16%	0.15%	0.14%	0.13%	0.11%	0.11%
Wallonia	0.27%	0.27%	0.26%	0.26%	0.26%	0.26%	0.27%	0.27%

Source : INS, Bureau Fédéral du Plan, Démographie mathématique, Perspectives de population 2000-2050 par arrondissement, Novembre 2001

Projections on the population of working age and the participation rate from the OECD have further used to estimate the labor supply growth rates. OECD estimates that population of working age will reach 6953.5 thousands in 2010 while the overall employment will rise from 59.3 per cent in 2003 to about 64.7 per cent of the working-age population in 2010 (OECD, 2005a).

The medium term trends for international oil prices remain highly uncertain. In the BAU scenario the assumptions regarding the crude oil price are based on projections from OECD and World Bank for the year 2005-2007, and on projections from the International Energy Agency for the medium term (see table 4.2).

[19] The simulations have been run with an aggregated version of GreenMod II model including 30 production sectors and 37 types of commodities, oligopolistic competition and increasing returns to scale, and two household income groups. The disaggregation of the production sectors and commodities used to run the policy simulations are provided in section 6.1.

Table 4.2. Assumptions regarding the price of crude oil

	2005	2006	2007	2008	2009	2010	2011	2012
Crude oil price (USD/barrel)	54.4	56.0	51.5	47.7	43.8	40	41	42

Source: OECD Economic Outlook (2005b), World Bank Global Economic Prospects (2006) and International Energy Agency, World Energy Outlook 2005

According to International Energy Agency (2005) the crude oil price is assumed to ease to around 40 USD[20] in 2010, and to rise slowly afterwards, in a more or less linear way, reaching close to 50 USD in 2020.

European gas import prices are linked to the price of oil products, although with a six- to nine-month time lag. Therefore, the gas import prices have risen steadily with the oil prices during the past few years, from 3.91 USD/MBtu in 2003 to 4.28 USD/MBtu in 2004 and 6.33 USD/MBtu in 2005 (OECD, 2005b). According to the International Energy Agency (2005), after the second half of the current decade the gas import prices are also assumed to decline, reaching 5 USD/MBtu in 2010. Starting with 2010 the gas import prices are assumed to grow slowly, up to 6.1 USD/MBtu in 2020 (International Energy Agency, 2005).

International steam coal prices have also risen steadily for the past few years, due to the strong demand and the rising oil prices. The OECD steam coal imports price increased by about 53 per cent per tonne during 2000-2004 (in year-2004 dollars), reaching 55 USD/tonne in 2004. In the BAU scenario it is further assumed the price to fall back to around 49 USD/tonne by 2010 and to rise slightly up to 50 USD/tonne in 2020 (International Energy Agency, 2005).

The assumptions related to the export prices of non-energy goods and services and import prices of non-energy goods and services in USD (see table 4.3) are based on the projections published by the Federal Planning Bureau of Belgium (2005), whereas the exchange rate (euro/USD) has been revised according to the latest estimates published by the OECD (2005b).

Table 4.3. Export and import prices of non-energy goods and services in USD (annual growth rates)

	2005	2006	2007	2008	2009	2010	2011	2012
Export prices of non-energy goods	5.30%	0.90%	1.00%	1.30%	1.50%	1.60%	1.60%	1.60%
Import prices of non-energy goods	4.80%	0.90%	1.10%	1.30%	1.50%	1.60%	1.60%	1.60%
Exchange rate USD/euro (x100)	124	117	117	117	117	117	117	117

Source: Federal Planning Bureau (2005) and OECD (2005b)

An average annual increase in the energy efficiency of 1.4 per cent has been assumed for 2005-2012 in the baseline, in line with the Federal Planning Bureau of Belgium projections (2005). The increase in the energy efficiency arises due to the high level of energy prices and the industrial restructuring.

Furthermore, an average annual increase in the total factor productivity of 1.1 per cent has been assumed in the baseline (Federal Planning Bureau, 2005; European Commission, 2006).

[20] The crude oil price is expressed in nominal terms, in year-2004 dollars.

4.1. Policy scenarios

a. A tax of 10€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)

In the first scenario, a tax of 10€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation by firms and households is implemented gradually starting with 2005. The tax reaches its target level of 10€/t of CO2 emissions in 2012. Given that the measure is expected to have a negative impact on the private consumption and on the economic activity, a revenue recycling scheme is implemented:

- The additional tax revenues corresponding to the consumption of gasoline and gas oil for private transportation are redistributed through a decrease in the personal income tax, while;
- The additional tax revenues corresponding to the consumption of gasoline and gas oil for transportation by the firms are recycled through a reduction in the corporate income tax.

b. A tax of 20€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)

The setting of the second policy scenario is similar to the first one. In this case, however, the target level for the tax, to be achieved in 2012, is established to 20€ per ton of CO2 emissions.

c. A tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households

The third scenario considers only the CO2 emissions related to the private consumption of fuels. A tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households is imposed gradually starting with 2005. Like in the first two scenarios, the tax target level of 10€ per ton is achieved in 2012. A recycling scheme is implemented to counterbalance the expected negative effects on private consumption, where the additional tax revenues are redistributed through a reduction in the personal income tax.

d. A tax of 20€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households

The fourth policy scenario is similar to the third one. The only difference resides in the target level established for the tax on CO2 emissions, to be achieved in 2012, which is set in this case to 20€ per ton.

e. The compliance with the voluntary agreements undertaken in Wallonia and Flanders

The fifth policy scenario evaluates the effects of the voluntary agreements undertaken in Wallonia and Flanders. These agreements are negotiated at sectoral level or by companies directly and imply a reduction of the greenhouse gases covered by the Kyoto Protocol and an increase in the energy efficiency by the companies.

In the Flemish region, the purpose of the sectoral agreements is first to reach a decrease of the emissions to the level of 1990, and then to further decrease them to reach the Kyoto target. Therefore, the Flemish region encourages the companies to reach the world best performance in the energy efficiency. Energy plans have been defined by sectors or firms in order to reach this efficiency. In exchange for the fulfillment of the energy plans, the regional Flemish government has agreed not to impose additional measures aiming at increasing the energy efficiency and reducing the GHG emissions, and has provided free emissions allowance equal to the target fixed in the energy plan. The companies who did not sign sectoral agreements will only receive a percentage of their current emissions as emissions allowances, and this percentage will be based on estimates of the reduction potential for the sector.

On November 29, 2002, the Flemish Covenant Energy Benchmarking was approved by the Flemish Government. By January 11, 2006, 179 firms as well as 14 sectoral organizations have signed an agreement.

In order to determine the best standard, different methodologies were applied: in case of the full benchmark where all comparable installations in the world are included, the target is to reach the world's best decile (the 10 per cent best industries). The benchmarking studies were conducted by independent consultants at the process installation level in order to obtain data that can be compared internationally. One year and a half (the latest) after entering the Covenant, each company or industry had to prepare the Energy plan analyzing the ways to reach and keep the best international standard. Monitoring and progress reports are drawn up by the industry from that point onwards, on a yearly basis. The working period for the Covenant is up to 2012.

A benchmarking commission has been created to, amongst other tasks, coordinate, supervise and monitor the progress made during the implementation of the Covenant. The commission is composed of representatives of the Flemish government and representatives of the industrial sectors.

A verification office is in charge of supervising the correct implementation of the benchmarking system and all calculations, and of reporting on the functioning of the system. The Verification Office is the only authority that judges individual cases; approves the methodology, the benchmark consultant and his study; verifies the determination of the gap from the best international standard, the submitted energy plan, the execution of the measures as well as the monitoring and reporting.

Based on the latest available evolution report, the following increase in the energy efficiency would be reached by 2012, taking 2003 as the base year (see table 4.4). These values have been used for setting up the fifth policy scenario, evaluated using the GreenMod II model.

Table 4.4. Increase in the energy efficiency to be achieved in Flanders by 2012, by industries undertaking sectoral agreements (base year 2003)

Sectors		IEE adjusted (%)
Manufacture of food products and beverages	SecE6	15.25
Manufacture of pulp, paper and paper products	SecE7	11.68
Manufacture of coke, refined petroleum products and nuclear fuel	SecE8	4.92
Manufacture of chemicals and chemical products	SecE9	9.48
Manufacture of other non-metallic mineral products	SecE10	
Ceramic		2.83
Glass		8.65
Manufacture of basic metals	SecE11	
Steel		4.92
Metallic		7.35
Manufacture of motor vehicles, trailers and semi-trailers	SecE18	7.35
Other manufacturing	SecE20	
Textile		10.10
Wood		0.28

Source: Commissie Benchmarking Vlaanderen, (2004), Evaluatieverslag 2002-2004 and own calculation.
Note: IEE represents the energy efficiency index.

Regarding Wallonia, various sectoral agreements have also been signed with local industries to reduce their CO2 emissions and to increase their energy efficiency.

The implementation of a sectoral agreement in Wallonia consists of four steps. The first step is the declaration of intention between the region and the concerned sectors. The second step consists of conducting energy audits in the major industries. These audits assess the company energy consumption and production. The specific consumption of different energy inputs is further evaluated and the total CO2 emissions are calculated. The process of production is analyzed in order to assess any possible reduction of direct greenhouse gases emissions, through an improvement of the production process and through the use of cleaner energy inputs. This process leads to the proposal of different short, medium and long term plans to improve the energy efficiency of the company. In the third step, the agreement is officially signed between the Government and the federation, while in the fourth step the agreement is implemented and monitored.

The Walloon government has agreed, in exchange for the implementation of the sectoral agreements, not to impose any other additional measures for increasing gains in energy efficiency or reducing the GHG emissions, on the concerned companies. For the first emission trading period (2005-2007) the government has granted the free allocation of emissions allowances for the sectors undertaking sectoral agreements, while preferential treatment is envisaged for the second trading period (2008-2012). In case of new entrants during the period 2005-2007, they will be granted free emission allowances using the allowances reserve.

By June 2004, a number of sectoral agreements were concluded with the Walloon Region. The agreements signed with the Multisector federation for the technology industry (AGORIA), Federation of Belgian dairy industry (CBL), Federation of Belgian cement industry (FEBELCEM), Federation of food industry (FEVIA), Federation of glass industry (FIV), Association of the Belgian pulp, Paper and Board Producers Association of the Belgian (COBELPA), Federation of chemical industries (FEDICHEM), CARMEUSE group and LHOIST group have already been published in the Belgian Official Monitor, together with their estimated increase in the energy efficiency. The sectoral agreement with the Belgian federation of bricks (FBB) and Federation of ceramic industry (FEDICER) is currently in the public consultation stage.

Based on these agreements, the increase in the energy efficiency by 2012, taking 2003 as the base year, has been used to set up the fifth policy scenario (see table 4.5). The energy efficiency index is derived as:

$$IEE(t) = \frac{Total\ energy\ consumption\ (t)}{Energy\ consumption\ per\ unit\ of\ production\ (0)\ \cdot Production\ level\ (t)} \cdot 100$$

where *t* stands for the current year and *0* stands for the base year. Energy consumption refers to the primary energy consumption in this case. The increase in the energy efficiency is given by the difference between 100 and the value of IEE derived in this fashion.

Table 4.5. Increase in the energy efficiency to be achieved in Wallonia by 2012, by industries undertaking sectoral agreements

Sectors		**IEE adjusted (%)**
Manufacture of food products and beverages	SecE6	
Agricultural products processing		6.03
Dairy products		6.02
Manufacture of pulp, paper and paper products	SecE7	14.08
Manufacture of coke, refined petroleum products and nuclear fuel	SecE8	5.56
Manufacture of chemicals and chemical products	SecE9	6.67
Manufacture of other non-metallic mineral products	SecE10	
Ceramic and bricks		3.04
Glass		6.38
Cement		5.70
Lime (Carmeuse)		1.05
Lime (Lhoist)		2.07
Manufacture of basic metals	SecE11	
Basic iron and steel		5.56
Casting of metals		7.21
Non-ferrous metals		12.67
Manufacture of fabricated metal products	SecE12	10.80
Manufacture of machinery and equipment n.e.c.	SecE13	10.80
Manufacture of other transport equipment	SecE19	10.80

Source: Plan sectoriel d'accord de branche and own calculations.
Note: IEE represents the energy efficiency index.

In the Brussels region, no sectoral agreements have been contracted given that the vast majority of emissions come from the residential sector, the services sector and the transportation sector.

4.2. Simulation results

a. A tax of 10€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)

The tax on CO2 emissions generated by the consumption of gasoline and gas oil for transportation by the firms and households has two main effects: a 'direct effect' through price increases, and an 'indirect effect' through the recycling of the additional fiscal revenues. The 'direct effect' through prices stimulates conservation measures, fuel substitution and changes in the economy's production and consumption structures, while the 'indirect effect' strengthens the previous effects by changing consumption and investment patterns.

As a 'direct effect' of the policy measure, consumer prices gross of taxes for gasoline and gas oil rise as much as 0.57 and 0.77 per cent, respectively, by 2012 compared with the baseline (see table 4.6).

Table 4.6. Sectoral effects of a tax of 10€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households) in 2012.

Sectoral effects	Regions		
	wal	vla	bru
Gasoline			
Consumer prices gross of taxes	0.58	0.57	0.57
Consumer prices net of taxes	-0.01	-0.01	-0.01
Private consumption	-0.39	-0.40	-0.36
Domestic sales	-0.97	-0.80	-0.70
Imports	-0.97	-0.81	-0.71
Gas oil			
Consumer prices gross of taxes	0.77	0.77	0.77
Consumer prices net of taxes	0.00	0.00	-0.01
Private consumption	-0.53	-0.54	-0.49
Domestic sales	-0.79	-0.67	-0.43
Imports	-0.79	-0.68	-0.44

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

Private consumption of both gasoline and gas oil declines during 2005-2012 exerting downwards pressure on the consumer prices net of taxes, and leading to a drop in the domestic sales (see table 4.6).

The negative impact of the policy measure on the private consumption is weakened by the 'indirect effect' through the recycling of the additional fiscal revenues. The tax revenues from the CO2 emissions generated by the consumption of gasoline and gas oil for transportation by the households allow reducing the personal income tax by 0.11 per cent in 2012 (see table 4.9). Thus, the disposable income of the first household income group (the population is divided into two income groups, the second being the richest half) increases, leading to a slight increase in its private consumption for most commodities (see table 6.9, appendix 3) except for gasoline, gas oil and transport services. For the second household income group in Wallonia and Flanders, the reduction in the personal income tax cannot overweight the drop in the gross income of this group. Therefore, the budget available for consumption of the second household income group in Wallonia and Flanders declines leading to a decrease in its private consumption for most commodities (see table 6.10, appendix 3).

As explained, the tax is also levied on the CO2 emissions generated by the consumption of gasoline and gas oil for transportation by firms. Implementing CO2 taxes on intermediate consumption affects firms' input choice. It generates an upwards shift in the cost curves of the production sectors and the demand for gasoline and gas oil falls (see tables 6.16 and 6.18, appendix 3). The relative increase in the gasoline and gas oil prices with respect to other factors of production also induces a substitution effect in favor of labor and capital.

The rise in the production costs negatively affects the profitability of the firms and leads to a decline in the output for most of the sectors. It further triggers a downward adjustment in other fuels, capital and labor demand (see table 6.7, appendix 3) which outweighs the substitution effects. Thus, the share of capital income in the value added declines.

The most affected sectors are the land and supporting and auxiliary transport activities (see table 4.7). The highest increase in the production costs corresponding to the land transport services arises in Wallonia followed by Flanders, due to the relatively larger share of gasoline and gas oil consumption in total production expenditures (see table 4.7). Demand for gasoline and gas oil, employment in the sectors and their profitability decline, followed by a drop in sectoral investments. The fall in production and the relative increase in domestic prices compared with the world prices further leads to a fall in exports of transport services (see table 4.7).

Table 4.7. Effects of the policy measure on the land transport, water transport and supporting and auxiliary transport activities in 2012

Sectoral results	Regions		
	wal	vla	bru
Land transport; transport via pipelines			
Price of domestic production	0.45	0.30	0.24
Domestic production	-0.93	-0.62	-0.28
Employment	-0.73	-0.47	-0.19
Gasoline consumption	-1.52	-1.28	-0.94
Gas oil consumption	-1.77	-1.53	-1.20
Investments	-0.16	-0.15	-0.16
Exports	-1.91	-1.27	-0.81
Supporting and auxiliary transport activities; activities of travel agencies			
Price of domestic production	0.19	0.01	0.05
Domestic production	-0.79	-0.23	-0.40
Employment	-0.65	-0.21	-0.35
Gasoline consumption	-0.76	-0.29	-0.23
Gas oil consumption	-1.65	-1.18	-1.12
Investments	-0.18	-0.16	-0.17
Exports	-1.18	-0.25	-0.50

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The fall in the domestic sales of gasoline and gas oil (see table 4.6), originating from both private consumption and intermediate consumption by the firms, triggers a downwards adjustment in the production of coke and refined petroleum products (see table 4.8) followed by a decline in employment by the sector in Flanders and Brussels. Investments in the sector decrease also due to the fall in the profitability. Similar to the transport services, exports in Wallonia and Flanders decline because the price on the domestic market becomes more interesting price wise and also due to the decline in the sectoral production.

Table 4.8. Effects of the policy measure on the manufacture of coke, refined petroleum products in 2012

Manufacture of coke, refined petroleum products and nuclear fuel	Regions		
	wal	vla	bru
Price of domestic production	0.03	-0.04	-0.23
Domestic production	-0.62	-0.23	-0.06
Employment	0.51	-0.64	-0.18
Investments	-0.16	-0.18	-0.16
Exports	-0.65	-0.19	0.15

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The demand for non-energy commodities by firms fall, overweighting the rise in the private demand. Thus, the domestic sales and imports of most products diminish. However, the relative increase in the production costs compared with the import prices leads to substitution effects towards imports for land transport services (see table 6.15, appendix 3).

The negative impact of the policy measure on the profitability of the firms in all the three regions and consequently on the sectoral investments (see table 6.13, appendix 3) is attenuated by the 'indirect effect' through the recycling of the CO2 tax revenues, which allow reducing the corporate income tax by 2.14 per cent in 2012.

At macro level, the retrenchment in national GDP is marginal, 0.04 per cent in 2012 compared with the baseline. The policy measure generates additional tax revenues of 234 millions euro in 2012 which allow a reduction of 0.11 per cent in the personal income tax and by 2.14 per cent in the corporate income tax. However, the cut in the corporate income tax cannot reverse the negative effect of the policy measure on employment, and therefore the unemployment rate increases by 0.04 percentage points in 2012 compared with the baseline (see table 4.9).

Table 4.9. Macroeconomic effects of the policy measure

	2005	2006	2007	2008	2009	2010	2011	2012
GDP (% change)	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04
National savings (% change)	-0.03	-0.06	-0.08	-0.11	-0.13	-0.15	-0.17	-0.19
Labor supply (% change)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	8.28	8.24	8.25	8.29	8.29	8.30	8.28	8.27
CO2 tax revenues (mil EUR)	29	58	87	116	144	171	202	234
Income tax (% change)	-0.02	-0.03	-0.04	-0.06	-0.07	-0.08	-0.10	-0.11
Corporate tax (% change)	-0.28	-0.55	-0.82	-1.09	-1.35	-1.59	-1.86	-2.14

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

At the regional level, the real GDP drops by 0.05 per cent in Wallonia, 0.04 per cent in Flanders and 0.03 per cent in Brussels in 2012 compared with the baseline. The largest negative effect on employment is observed in Wallonia, where the unemployment rate rises by 0.05 percentage points, followed by Flanders with 0.04 percentage points and Brussels with 0.03 percentage points. Thus, the negative effects in terms of both GDP and unemployment at national and regional levels are marginal.

Table 4.10. Regional effects of the policy measure

		2005	2006	2007	2008	2009	2010	2011	2012
Labor supply (% change)	**wal**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**vla**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**bru**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	**wal**	10.90	10.83	10.84	10.87	10.87	10.88	10.88	10.89
Unemployment rate (%)	**vla**	5.58	5.55	5.59	5.64	5.66	5.67	5.65	5.63
Unemployment rate (%)	**bru**	15.81	15.70	15.61	15.54	15.46	15.39	15.36	15.33
Regional GDP (% change)	**wal**	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05
Regional GDP (% change)	**vla**	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04
Regional GDP (% change)	**bru**	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

As already explained, the 'direct effect' through prices stimulates conservation measures and fuels substitution, leading to CO2 emissions abatement. CO2 emissions at the national level gradually decline starting with 2005 up to 0.30 per cent in 2012 compared with the baseline. In 2012 the tax rate reaches the targeted level of 10€ per ton of CO2 emissions. At the regional level, Wallonia achieves the highest reduction in relative terms by 2012, 0.35 per cent compared with the baseline, followed by Brussels with 0.29 per cent and Flanders with 0.26 per cent (see table 4.11). With regard to the CO2 emissions generated by the consumption of gasoline and gas oil for transportation by households, the highest abatement is attained in Wallonia, 0.38 per cent in 2012 compared with the baseline, due to the larger share of fuels subject to the CO2 tax in the households consumption budget relative to the other two regions (see table 4.11).

Table 4.11. Effects of the policy measure on the CO2 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CO2 emissions		-0.04	-0.07	-0.11	-0.15	-0.18	-0.22	-0.26	-0.30
National CO2 emissions (kt)		123,201	123,688	125,145	126,572	128,023	128,017	128,281	128,560
Regional CO2 emissions	**wal**	-0.05	-0.09	-0.14	-0.18	-0.22	-0.27	-0.31	-0.35
Regional CO2 emissions	**vla**	-0.03	-0.06	-0.09	-0.13	-0.16	-0.20	-0.23	-0.26
Regional CO2 emissions	**bru**	-0.04	-0.07	-0.11	-0.14	-0.18	-0.22	-0.25	-0.29
Regional CO2 emissions (kt)	**wal**	43,818	44,256	45,037	45,799	46,594	45,917	46,185	46,458
Regional CO2 emissions (kt)	**vla**	75,418	75,404	75,919	76,422	76,909	77,396	77,316	77,244
Regional CO2 emissions (kt)	**bru**	3,964	4,028	4,189	4,351	4,520	4,704	4,780	4,858
Household CO2 emissions	**wal**	-0.05	-0.09	-0.14	-0.19	-0.24	-0.29	-0.34	-0.38
Household CO2 emissions	**vla**	-0.04	-0.09	-0.14	-0.18	-0.23	-0.28	-0.33	-0.37
Household CO2 emissions	**bru**	-0.03	-0.06	-0.09	-0.12	-0.15	-0.19	-0.22	-0.25
Household CO2 emissions (kt)	**wal**	11,609	11,898	12,209	12,533	12,882	13,264	13,385	13,507
Household CO2 emissions (kt)	**vla**	21,321	21,611	22,058	22,521	23,020	23,579	23,600	23,621
Household CO2 emissions (kt)	**bru**	2,279	2,322	2,433	2,546	2,667	2,800	2,848	2,897

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The fall in the private and intermediate consumption of gasoline and gas oil further leads to a drop in the CH4 emissions generated by households and firms. However, by 2012 the CH4 emissions at the national level only reduce by 0.02 per cent compared with the baseline (see table 4.12). The reason stems from the high share of process emissions in the total CH4 emissions.

Table 4.12. Effects of the policy measure on the CH4 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CH4 emissions		0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
National CH4 emissions (kt)		7,834	7,757	7,684	7,612	7,543	7,476	7,406	7,339
Regional CH4 emissions	**wal**	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04
Regional CH4 emissions	**vla**	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Regional CH4 emissions	**bru**	-0.08	-0.16	-0.24	-0.32	-0.39	-0.47	-0.55	-0.63
Regional CH4 emissions (kt)	**wal**	2,385	2,361	2,338	2,317	2,296	2,276	2,253	2,232
Regional CH4 emissions (kt)	**vla**	5,440	5,387	5,336	5,285	5,237	5,189	5,142	5,095
Regional CH4 emissions (kt)	**bru**	9	9	10	10	11	11	11	12
Household CH4 emissions	**wal**	-0.06	-0.12	-0.18	-0.24	-0.31	-0.37	-0.43	-0.50
Household CH4 emissions	**vla**	-0.06	-0.12	-0.18	-0.25	-0.31	-0.38	-0.44	-0.50
Household CH4 emissions	**bru**	-0.05	-0.11	-0.16	-0.22	-0.28	-0.34	-0.39	-0.45
Household CH4 emissions (kt)	**wal**	57	60	62	64	67	69	71	72
Household CH4 emissions (kt)	**vla**	21	22	23	24	25	26	27	27
Household CH4 emissions (kt)	**bru**	4	4	5	5	5	6	6	6

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The N2O emissions at the national level decline by 0.20 per cent in 2012 compared with the baseline (see table 4.13). Due to the large share of process emissions in the total N2O emissions, the tax on CO2 emissions has relatively little effect with regard to their abatement.

Table 4.13. Effects of the policy measure on the N2O emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National N2O emissions		-0.02	-0.04	-0.07	-0.09	-0.12	-0.15	-0.17	-0.20
National N2O emissions (kt)		11,561	11,444	11,339	11,236	11,138	11,043	10,923	10,807
Regional N2O emissions	**wal**	-0.02	-0.04	-0.06	-0.09	-0.11	-0.14	-0.17	-0.20
Regional N2O emissions	**vla**	-0.02	-0.04	-0.06	-0.09	-0.11	-0.14	-0.17	-0.20
Regional N2O emissions	**bru**	-0.08	-0.15	-0.23	-0.30	-0.38	-0.45	-0.52	-0.60
Regional N2O emissions (kt)	**wal**	3,757	3,697	3,641	3,586	3,533	3,481	3,424	3,369
Regional N2O emissions (kt)	**vla**	7,700	7,641	7,587	7,535	7,485	7,436	7,371	7,309
Regional N2O emissions (kt)	**bru**	104	105	110	115	120	126	128	130
Household N2O emissions	**wal**	-0.06	-0.12	-0.18	-0.24	-0.31	-0.37	-0.43	-0.50
Household N2O emissions	**vla**	-0.06	-0.12	-0.18	-0.25	-0.31	-0.38	-0.44	-0.50
Household N2O emissions	**bru**	-0.05	-0.11	-0.16	-0.22	-0.28	-0.34	-0.39	-0.45
Household N2O emissions (kt)	**wal**	18	19	19	20	21	22	22	23
Household N2O emissions (kt)	**vla**	476	494	514	535	558	584	595	607
Household N2O emissions (kt)	**bru**	43	44	47	49	52	56	57	57

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

b. A tax of 20€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households)

The setting of the second policy scenario is similar to the first one, but the target level for the tax that has to be reached by 2012 is doubled, 20€ per ton of CO2 emissions. Thus, the impact of this policy scenario is comparable to the previous one in terms of direction of changes although their magnitude is different. It should be emphasized that due to the relative price changes which lead to various substitution effects through complex mechanisms, the effects of the policy measure are not necessarily doubled compared with the previous policy scenario.

Consumer prices gross of taxes for gasoline and gas oil increase by more than 1.15 per cent in 2012 compared with the baseline, leading to a downwards adjustment in the private consumption at the regional level (see table 4.14). In this case, the CO2 tax revenues allow the government to reduce the personal income tax by 0.22 per cent in 2012 (see table 4.17). The negative effects on the private consumption of gasoline and gas oil are therefore weakened by the rise in the household budget available for consumption. Like in the previous scenario, demand by the first household income group for all products, except the fuels subject to CO2 tax and the transport services, enlarges (see table 6.31, appendix 3). Demand by the second household income group for most products declines but the size of the effect is marginal, except for the consumption of gasoline, gas oil and transport services (see table 6.32, appendix 3).

Table 4.14. Sectoral effects of a tax of 20€ per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households) in 2012

Sectoral effects	Regions		
	wal	vla	bru
Gasoline			
Consumer prices gross of taxes	1.15	1.15	1.15
Consumer prices net of taxes	-0.02	-0.02	-0.02
Private consumption	-0.77	-0.79	-0.73
Domestic sales	-1.90	-1.58	-1.38
Imports	-1.91	-1.59	-1.39
Gas oil			
Consumer prices gross of taxes	1.55	1.55	1.54
Consumer prices net of taxes	-0.01	-0.01	-0.01
Private consumption	-1.05	-1.07	-0.98
Domestic sales	-1.56	-1.32	-0.86
Imports	-1.56	-1.33	-0.87

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The tax on the CO2 emissions generated by the consumption of gasoline and gas oil for transportation by firms leads to an upwards shift in the cost curves of the production sectors and a decline in the gasoline and gas oil demand (see table 6.38 and 6.40, appendix 3). It further results in substitution effects in favor of labor and capital due to the relative increase in the gasoline and gas oil prices with respect to other factors of production.

The highest negative impact at the sectoral level is observed in the transport services (see table 4.15). The explanation resides in the larger share of gasoline and gas oil expenditures in the total production costs. Thus, transport sectors' profitability declines leading to a fall in the employment by the sectors and a reduction in investments.

Table 4.15. Effects of the policy measure on the land transport, water transport and supporting and auxiliary transport activities in 2012

Sectoral results	**Regions**		
	wal	**vla**	**bru**
Land transport; transport via pipelines			
Price of domestic production	0.91	0.60	0.48
Domestic production	-1.83	-1.23	-0.56
Employment	-1.45	-0.94	-0.38
Gasoline consumption	-2.97	-2.51	-1.85
Gas oil consumption	-3.45	-2.98	-2.34
Investments	-0.32	-0.31	-0.32
Exports	-3.77	-2.51	-1.60
Supporting and auxiliary transport activities; activities of travel agencies			
Price of domestic production	0.38	0.03	0.10
Domestic production	-1.57	-0.45	-0.79
Employment	-1.30	-0.41	-0.70
Gasoline consumption	-1.52	-0.57	-0.47
Gas oil consumption	-3.24	-2.30	-2.21
Investments	-0.37	-0.32	-0.34
Exports	-2.36	-0.51	-1.01

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The policy measure also triggers a drop in the production of coke and refined petroleum products, followed by the employment decline in Flanders and Brussels and a reduction in the investments (see table 4.16). The relative increase in the domestic prices of both transport services and production of coke and refined petroleum products compared with the world market prices leads to a reorientation of domestic producers towards domestic markets and thus exports decline in Wallonia and Flanders (see tables 4.15-4.16).

Table 4.16. Effects of the policy measure on the manufacture of coke, refined petroleum products in 2012

Manufacture of coke, refined petroleum products and nuclear fuel	**Regions**		
	wal	**vla**	**bru**
Price of domestic production	0.07	-0.09	-0.45
Domestic production	-1.22	-0.46	-0.11
Employment	1.00	-1.28	-0.35
Investments	-0.32	-0.36	-0.31
Exports	-1.29	-0.39	0.29

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The negative effect on firms' profitability is weakened by the fall in the corporate income tax, by 4.22 per cent in 2012, which is achieved due to additional CO2 tax revenues generated by the consumption of gasoline and gas oil for transportation by firms.

The impact on the GDP is marginal at both the national and regional levels (see tables 4.17 and 4.18). At the national level, real GDP drops by 0.08 per cent compared with the baseline, while at the regional level, the highest GDP decline is attained in Wallonia, 0.10 per cent compared with the baseline, followed by Flanders with 0.08 per cent and Brussels with 0.07 per cent. Furthermore, at the national level the unemployment rate rises with 0.08 percentage points in 2012 compared with the baseline, while at the regional level with 0.09 percentage points in Wallonia, 0.08 percentage points in Flanders and 0.06 percentage points in Brussels.

Table 4.17. Macroeconomic effects of the policy measure

	2005	2006	2007	2008	2009	2010	2011	2012
GDP (% change)	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08
National savings (% change)	-0.06	-0.11	-0.16	-0.21	-0.26	-0.30	-0.34	-0.39
Labor supply (% change)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	8.29	8.25	8.27	8.31	8.32	8.33	8.32	8.31
CO2 tax revenues (mil EUR)	59	117	174	231	286	340	402	465
Income tax (% change)	-0.03	-0.06	-0.09	-0.11	-0.14	-0.16	-0.19	-0.22
Corporate tax (% change)	-0.56	-1.10	-1.64	-2.17	-2.67	-3.15	-3.69	-4.22

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The total CO2 tax revenues generated by the measure amount to 465 millions euro, which allow a reduction in the personal income tax by 0.22 per cent and in the corporate income tax by 4.22 per cent in 2012 (see table 4.17).

Table 4.18. Regional effects of the policy measure

		2005	2006	2007	2008	2009	2010	2011	2012
Labor supply (% change)	**wal**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**vla**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**bru**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	**wal**	10.91	10.84	10.86	10.90	10.91	10.91	10.93	10.93
Unemployment rate (%)	**vla**	5.58	5.57	5.61	5.66	5.68	5.70	5.69	5.67
Unemployment rate (%)	**bru**	15.81	15.71	15.62	15.56	15.49	15.42	15.39	15.36
Regional GDP (% change)	**wal**	-0.01	-0.03	-0.04	-0.05	-0.06	-0.07	-0.09	-0.10
Regional GDP (% change)	**vla**	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08
Regional GDP (% change)	**bru**	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

CO2 emissions at the national level fall smoothly by 2012. In 2012, when the CO2 tax reaches the target level of 20€ per ton, CO2 emissions decline by 0.58 per cent compared to the baseline. The patterns at the regional level are similar to the first policy scenario, with Wallonia achieving the largest emissions reduction, followed by Brussels and Flanders (see table 4.19).

Table 4.19. Effects of the policy measure on the CO2 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CO2 emissions		-0.07	-0.15	-0.22	-0.29	-0.36	-0.44	-0.51	-0.58
National CO2 emissions (kt)		123,156	123,597	125,009	126,389	127,792	127,736	127,955	128,189
Regional CO2 emissions	**wal**	-0.09	-0.18	-0.27	-0.35	-0.44	-0.53	-0.61	-0.70
Regional CO2 emissions	**vla**	-0.06	-0.13	-0.19	-0.25	-0.32	-0.39	-0.45	-0.52
Regional CO2 emissions	**bru**	-0.07	-0.14	-0.21	-0.28	-0.36	-0.44	-0.50	-0.57
Regional CO2 emissions (kt)	**wal**	43,799	44,215	44,977	45,718	46,493	45,797	46,045	46,298
Regional CO2 emissions (kt)	**vla**	75,395	75,357	75,848	76,326	76,787	77,245	77,142	77,047
Regional CO2 emissions (kt)	**bru**	3,963	4,025	4,185	4,345	4,512	4,694	4,768	4,844
Household CO2 emissions	**wal**	-0.09	-0.19	-0.28	-0.38	-0.47	-0.58	-0.67	-0.76
Household CO2 emissions	**vla**	-0.09	-0.18	-0.27	-0.36	-0.46	-0.56	-0.65	-0.74
Household CO2 emissions	**bru**	-0.05	-0.11	-0.17	-0.23	-0.30	-0.37	-0.43	-0.49
Household CO2 emissions (kt)	**wal**	11,604	11,887	12,192	12,510	12,851	13,226	13,341	13,455
Household CO2 emissions (kt)	**vla**	21,311	21,592	22,028	22,480	22,967	23,513	23,523	23,534
Household CO2 emissions (kt)	**bru**	2,278	2,320	2,431	2,543	2,663	2,794	2,842	2,890

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The policy measure also leads to CH4 and N2O emissions abatement, although the relative size of their reduction is small (see tables 4.20 and 4.21). As already explained, the reason stands in the large share of process emissions corresponding to CH4 and N2O.

Table 4.20. Effects of the policy measure on the CH4 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CH4 emissions		-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.05
National CH4 emissions (kt)		7,834	7,757	7,683	7,611	7,542	7,475	7,405	7,337
Regional CH4 emissions	**wal**	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08
Regional CH4 emissions	**vla**	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.03
Regional CH4 emissions	**bru**	-0.16	-0.32	-0.48	-0.63	-0.78	-0.93	-1.08	-1.23
Regional CH4 emissions (kt)	**wal**	2,384	2,361	2,338	2,316	2,295	2,275	2,252	2,231
Regional CH4 emissions (kt)	**vla**	5,440	5,387	5,335	5,285	5,236	5,189	5,141	5,095
Regional CH4 emissions (kt)	**bru**	9	9	10	10	11	11	11	11
Household CH4 emissions	**wal**	-0.12	-0.24	-0.36	-0.49	-0.61	-0.74	-0.86	-0.98
Household CH4 emissions	**vla**	-0.12	-0.24	-0.36	-0.49	-0.62	-0.75	-0.87	-1.00
Household CH4 emissions	**bru**	-0.10	-0.21	-0.32	-0.43	-0.55	-0.68	-0.79	-0.90
Household CH4 emissions (kt)	**wal**	57	59	62	64	66	69	71	72
Household CH4 emissions (kt)	**vla**	21	22	23	24	25	26	26	27
Household CH4 emissions (kt)	**bru**	4	4	5	5	5	6	6	6

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

At the national level, CH4 emissions drop by 0.05 per cent in 2012 compared with the baseline, while at the national level Brussels achieves the highest reduction, with 1.23 per cent, followed by Wallonia with 0.08 per cent and Flanders with 0.03 per cent (see table 4.20). The effect on the N2O emissions is slightly higher, achieving 0.40 per cent reduction at the national level in 2012 (see table 4.21).

Table 4.21. Effects of the policy measure on the N2O emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National N2O emissions		-0.04	-0.08	-0.13	-0.18	-0.23	-0.29	-0.34	-0.40
National N2O emissions (kt)		11,559	11,439	11,331	11,226	11,125	11,027	10,904	10,786
Regional N2O emissions	**wal**	-0.04	-0.08	-0.13	-0.17	-0.22	-0.28	-0.33	-0.39
Regional N2O emissions	**vla**	-0.04	-0.08	-0.13	-0.18	-0.23	-0.29	-0.34	-0.39
Regional N2O emissions	**bru**	-0.15	-0.31	-0.46	-0.60	-0.74	-0.89	-1.03	-1.18
Regional N2O emissions (kt)	**wal**	3,756	3,696	3,639	3,583	3,529	3,476	3,419	3,363
Regional N2O emissions (kt)	**vla**	7,699	7,638	7,582	7,528	7,477	7,425	7,359	7,295
Regional N2O emissions (kt)	**bru**	104	105	110	115	120	125	127	129
Household N2O emissions	**wal**	-0.12	-0.24	-0.36	-0.49	-0.61	-0.74	-0.86	-0.98
Household N2O emissions	**vla**	-0.12	-0.24	-0.36	-0.49	-0.62	-0.75	-0.87	-1.00
Household N2O emissions	**bru**	-0.10	-0.21	-0.32	-0.43	-0.55	-0.68	-0.79	-0.90
Household N2O emissions (kt)	**wal**	18	19	19	20	21	22	22	22
Household N2O emissions (kt)	**vla**	476	494	513	534	557	582	593	604
Household N2O emissions (kt)	**bru**	43	44	47	49	52	55	56	57

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

c. *A tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households*

Like in the previous two policy scenarios, the tax on the CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households exerts a 'direct effect' through price increases and an 'indirect effect' through the recycling of the additional fiscal revenues. However, in this case the change in the private consumption patterns is the driving force stimulating conservation measures and further leads to modifications in the production structure. Moreover, the 'indirect effect' is only channelled through the decrease in the personal income tax.

By 2012 consumer price gross of taxes for coal is expected to rise by about 20 per cent compared with the baseline, while the price of gasoline by about 0.50 per cent, the price of gas oil by 2.5 per cent and the price of natural gas by about 5.5 per cent in all three Belgian regions (see table 4.22). The differences between the consumer prices at the regional level are marginal. They arise due to the different composition of domestic fuels supply in terms of shares of imports and supply from the domestic producers. Subsequently, private consumption of coal, gasoline, gas oil and natural gas decreases (see table 4.22).

Table 4.22. Sectoral effects of a tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households in 2012

Sectoral effects	Regions		
	wal	vla	bru
Coal			
Consumer prices gross of taxes	19.90	19.90	19.90
Consumer prices net of taxes	-0.09	-0.09	-0.09
Private consumption	-11.94	-11.69	-12.69
Domestic sales	-0.99	-0.62	-0.74
Imports	-0.99	-0.62	-0.74
Gasoline			
Consumer prices gross of taxes	0.50	0.50	0.50
Consumer prices net of taxes	-0.09	-0.09	-0.09
Private consumption	-0.26	-0.27	-0.31
Domestic sales	-0.11	-0.09	-0.11
Imports	-0.11	-0.09	-0.11
Gas oil			
Consumer prices gross of taxes	2.53	2.53	2.53
Consumer prices net of taxes	-0.09	-0.09	-0.09
Private consumption	-1.64	-1.66	-1.66
Domestic sales	-0.22	-0.21	-0.15
Imports	-0.22	-0.21	-0.15
Natural gas			
Consumer prices gross of taxes	5.67	5.55	5.44
Consumer prices net of taxes	-0.97	-1.09	-1.19
Private consumption	-3.20	-3.20	-3.18
Domestic sales	-0.74	-1.03	-0.64
Imports	-2.67	-3.21	-3.04

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The highest decline in the private consumption in all three regions is attributed to coal, about 12 per cent in 2012 compared with the baseline. However, coal consumption represents less than 0.2 per cent of the household consumption budget in all the three regions, the 12 per cent fall in coal consumption thus being marginal. Private consumption of gas oil diminishes by 1.6 per cent and gasoline consumption by about 0.3 per cent in 2012 compared with the baseline.

The relatively higher increase in the price of natural gas compared with the price of gas oil and gasoline leads to a stronger negative effect on the private consumption of natural gas. Thus, consumption of natural gas declines by about 3.2 per cent. The different impact of the CO2 tax on the natural gas price compared with the gas oil and gasoline prices arises mainly because the rise in the consumer price of natural gas in the absence of CO2 taxes (in the baseline scenario) is slower compared with the gas oil and gasoline prices. As a consequence, the share of CO2 taxation in the price of natural gas becomes relatively higher compared with the gas oil and gasoline, although the absolute level of the tax per unit of energy content is higher for the gas oil and gasoline.

The fall in the private consumption of fuels is restrained by the 'indirect effect' through the recycling of additional CO2 tax revenues. The 0.45 per cent reduction in the personal income tax, achieved by 2012, leads to an improvement of the household budget disposable for consumption and attenuates the negative effect on the private consumption of fuels. Furthermore, the rise in household budget disposable for consumption in all three regions and the relative increase in consumer prices (including taxes) for fuels subject to a CO2 tax compared with other commodities results in a rise of consumption demand for non-energy goods by both income groups (see tables 6.53 and 6.54, appendix 3).

At the regional level, the relatively larger increase in the household consumption budget in Wallonia and Flanders together with the relative price changes of coal, gasoline, gas oil and natural gas among the regions yields a higher decline in the private consumption of coal and gasoline in Brussels compared with the other two regions. With regard to the private consumption of natural gas the largest negative impact is attained in Wallonia and Flanders even though the demand for natural gas in the household consumption budget is slightly different, with 1.1 per cent in Brussels, 0.7 per cent in Flanders and 0.5 per cent in Wallonia. The explanation stands in the lower increase in the price of natural gas in Brussels relative to the other two Belgian regions.

The fall in the domestic sales of gasoline and gas oil exerts a downward pressure on the consumer prices net of taxes, the output price and the profitability of coke and refined petroleum products sector (see table 4.23). Consequently, the sectoral gross output diminishes in all the three regions. The relatively larger drop, 0.16 per cent, in the production of coke and refined petroleum products in Wallonia compared with the other regions is due to the higher decline of the domestic sales of gasoline and gas oil in the region. The output fall leads to a decline in the employment in Flanders and Brussels. Further, the decline in the sectoral profitability leads to a reduction in investments carried out in the sector (see table 4.23).

Table 4.23. Effects of the policy measure on the manufacture of coke, refined petroleum products and nuclear fuel sector in 2012

Manufacture of coke, refined petroleum products and nuclear fuel	Regions		
	wal	vla	bru
Price of domestic production	-0.08	-0.10	-0.13
Domestic production	-0.16	-0.04	-0.03
Employment	0.04	-0.07	-0.07
Investments	-0.31	-0.30	-0.30
Exports	-0.17	-0.02	0.01

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

Similar effects in terms of output, investment and employment can be observed for the production and distribution of natural gas (see table 4.24). Nevertheless, the highest impact on the sectoral output arises in Wallonia and Flanders due to the relatively larger decline in the regional domestic sales compared with Brussels. Furthermore, the negative effect on employment is more significant, compared with the one on coke, refined petroleum products and nuclear fuel sector, due to the larger share of labor outlays in the sectoral production (15 per cent in Wallonia, 15 per cent in Flanders and 13 per cent in Brussels for the production and distribution of natural gas).

Table 4.24. Effects of the policy measure on the production and distribution of natural gas in 2012

Production and distribution of natural gas	Regions		
	wal	vla	bru
Price of domestic production	-1.12	-1.13	-0.93
Domestic production	-0.36	-0.36	-0.27
Employment	-0.89	-0.88	-0.67
Investments	-0.38	-0.37	-0.36
Exports	1.95	1.97	1.60

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

For the coal, given that all supply originates from the external sector, the drop in the domestic sales has a direct effect on imports (see table 4.22).

Domestic sales of most products decline, leading to a drop in the gross output of the corresponding production sectors and to a decrease in imports (see table 6.56, appendix 3).

The policy measure generates additional tax revenues equivalent to 173 millions euro in 2012, which could lead to a decrease in the personal income tax by 0.45 per cent. The negative effects in terms of real GDP are small during 2005-2012, while the unemployment rate rises by 0.03 percentage points in 2012 compared with the baseline (see table 4.25).

Table 4.25. Macroeconomic effects of the policy measure

	2005	2006	2007	2008	2009	2010	2011	2012
GDP (% change)	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.05
National savings (% change)	-0.06	-0.12	-0.17	-0.22	-0.27	-0.32	-0.37	-0.43
Labor supply (% change)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	8.28	8.24	8.25	8.28	8.29	8.29	8.28	8.26
Exchange rate (% change)	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.09
CO2 tax revenues (mil EUR)	21	41	62	83	105	126	150	173
Income tax (% change)	-0.06	-0.12	-0.18	-0.23	-0.29	-0.34	-0.39	-0.45

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The impact on the real GDP and unemployment at the regional level is also very small. The highest drop in the regional GDP is achieved in 2012 when the CO2 tax reaches the targeted level of 10€ per ton. However, it only reflects a 0.06 per cent decline in Wallonia compared with the baseline, and 0.05 per cent in Flanders and Brussels (see table 4.26).

Table 4.26. Regional effects of the policy measure

		2005	2006	2007	2008	2009	2010	2011	2012
Labor supply (% change)	**wal**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**vla**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**bru**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	**wal**	10.90	10.83	10.83	10.86	10.87	10.87	10.87	10.88
Unemployment rate (%)	**vla**	5.58	5.55	5.59	5.63	5.65	5.67	5.65	5.62
Unemployment rate (%)	**bru**	15.81	15.71	15.61	15.54	15.47	15.40	15.37	15.34
Regional GDP (% change)	**wal**	-0.01	-0.01	-0.02	-0.03	-0.04	-0.05	-0.05	-0.06
Regional GDP (% change)	**vla**	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.05
Regional GDP (% change)	**bru**	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04	-0.05

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The CO2 emissions at the national level decline by 0.67 per cent in 2012 compared with the baseline. The highest emission reduction at the regional level is achieved in Brussels, 1.29 per cent, due to the large share of emissions originating from the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households in this region, followed by Wallonia with 0.68 per cent and Flanders with 0.62 per cent (see table 4.27). However, the highest emission abatement in volume is achieved in Flanders.

Table 4.27. Effects of the policy measure on the CO2 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CO2 emissions		-0.08	-0.16	-0.24	-0.32	-0.41	-0.50	-0.59	-0.67
National CO2 emissions (kt)		123,149	123,583	124,983	126,349	127,736	127,660	127,863	128,078
Regional CO2 emissions	**wal**	-0.08	-0.16	-0.24	-0.33	-0.41	-0.51	-0.60	-0.68
Regional CO2 emissions	**vla**	-0.07	-0.15	-0.22	-0.30	-0.38	-0.47	-0.54	-0.62
Regional CO2 emissions	**bru**	-0.16	-0.32	-0.48	-0.64	-0.81	-0.97	-1.13	-1.29
Regional CO2 emissions (kt)	**wal**	43,803	44,224	44,988	45,731	46,505	45,804	46,052	46,304
Regional CO2 emissions (kt)	**vla**	75,387	75,340	75,822	76,289	76,739	77,187	77,072	76,965
Regional CO2 emissions (kt)	**bru**	3,959	4,018	4,174	4,329	4,492	4,669	4,738	4,809
Household CO2 emissions	**wal**	-0.29	-0.58	-0.87	-1.16	-1.44	-1.73	-2.00	-2.28
Household CO2 emissions	**vla**	-0.27	-0.53	-0.79	-1.06	-1.32	-1.59	-1.84	-2.10
Household CO2 emissions	**bru**	-0.29	-0.58	-0.87	-1.16	-1.45	-1.74	-2.02	-2.30
Household CO2 emissions (kt)	**wal**	11,580	11,840	12,120	12,412	12,726	13,072	13,161	13,249
Household CO2 emissions (kt)	**vla**	21,273	21,516	21,912	22,323	22,768	23,270	23,241	23,212
Household CO2 emissions (kt)	**bru**	2,273	2,309	2,414	2,519	2,632	2,756	2,796	2,837

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

At the sectoral level the highest emission reduction is in the production and distribution of natural gas and manufacturing of coke and refined petroleum products (see table 6.47, appendix 3). However, CO2 emissions of most production sectors rise. This effect occurs due to the substitution effects towards energy which are not subject to the CO2 tax.

The decline in the fuel consumption subject to the CO2 tax by the households also leads to a drop in the CH4 emissions. However, at the national level the reduction in the CH4 emissions is marginal, 0.02 cent in 2012 compared with the baseline, due to the important share of process emissions in the total CH4 emissions (see table 4.28).

Table 4.28. Effects of the policy measure on the CH4 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CH4 emissions		0.00	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
National CH4 emissions (kt)		7,834	7,757	7,684	7,612	7,543	7,476	7,406	7,339
Regional CH4 emissions	**wal**	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.05
Regional CH4 emissions	**vla**	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01
Regional CH4 emissions	**bru**	-0.07	-0.14	-0.22	-0.30	-0.39	-0.48	-0.56	-0.64
Regional CH4 emissions (kt)	**wal**	2,385	2,361	2,338	2,316	2,296	2,276	2,253	2,231
Regional CH4 emissions (kt)	**vla**	5,440	5,387	5,336	5,285	5,237	5,189	5,142	5,096
Regional CH4 emissions (kt)	**bru**	9	9	10	10	11	11	11	12
Household CH4 emissions	**wal**	-0.16	-0.33	-0.49	-0.66	-0.83	-1.00	-1.16	-1.33
Household CH4 emissions	**vla**	-0.15	-0.31	-0.47	-0.64	-0.80	-0.97	-1.12	-1.28
Household CH4 emissions	**bru**	-0.14	-0.28	-0.43	-0.58	-0.74	-0.91	-1.05	-1.20
Household CH4 emissions (kt)	**wal**	57	59	62	64	66	69	70	72
Household CH4 emissions (kt)	**vla**	21	22	23	24	25	26	26	27
Household CH4 emissions (kt)	**bru**	4	4	5	5	5	6	6	6

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

Similarly, the N2O emissions by the households fall due to the decline in the consumption of fuels subject to the CO2 tax. All in all, the measure leads to a reduction by 0.10 per cent in national N2O emissions in 2012, compared with the baseline (see table 4.29). Again the low N2O emissions abatement achieved at the national level is due to the large share of process emissions in the total N2O emissions.

Table 4.29. Effects of the policy measure on the N2O emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National N2O emissions		-0.01	-0.02	-0.03	-0.04	-0.06	-0.07	-0.09	-0.10
National N2O emissions (kt)		11,562	11,446	11,343	11,241	11,145	11,052	10,933	10,819
Regional N2O emissions	**wal**	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
Regional N2O emissions	**vla**	-0.01	-0.03	-0.04	-0.06	-0.07	-0.09	-0.11	-0.13
Regional N2O emissions	**bru**	-0.06	-0.12	-0.19	-0.26	-0.33	-0.41	-0.48	-0.54
Regional N2O emissions (kt)	**wal**	3,757	3,699	3,644	3,589	3,536	3,486	3,429	3,375
Regional N2O emissions (kt)	**vla**	7,701	7,642	7,589	7,537	7,488	7,440	7,376	7,314
Regional N2O emissions (kt)	**bru**	104	105	110	115	120	126	128	130
Household N2O emissions	**wal**	-0.16	-0.33	-0.49	-0.66	-0.83	-1.00	-1.16	-1.33
Household N2O emissions	**vla**	-0.15	-0.31	-0.47	-0.64	-0.80	-0.97	-1.12	-1.28
Household N2O emissions	**bru**	-0.14	-0.28	-0.43	-0.58	-0.74	-0.91	-1.05	-1.20
Household N2O emissions (kt)	**wal**	18	19	19	20	21	22	22	22
Household N2O emissions (kt)	**vla**	475	493	512	533	556	581	591	602
Household N2O emissions (kt)	**bru**	43	44	47	49	52	55	56	57

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

d. A tax of 20€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households

In terms of the direction of the effects the forth policy scenario is similar to the one corresponding to the tax of 10€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households. However, the magnitude of the effects is different.

By 2012 the impact on the consumer prices gross of taxes for coal, gasoline, gas oil and natural gas is almost doubled compared with the 10€ per ton of CO2 emissions scenario. As a result, the private consumption of fuels subject to the CO2 tax declines (see table 4.30).

Table 4.30. Sectoral effects of a tax of 20€ per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households

Sectoral effects	Regions		
	wal	vla	bru
Coal			
Consumer prices gross of taxes	39.77	39.77	39.77
Consumer prices net of taxes	-0.17	-0.17	-0.17
Private consumption	-20.46	-20.05	-21.76
Domestic sales	-1.73	-1.10	-1.30
Imports	-1.73	-1.10	-1.30
Gasoline			
Consumer prices gross of taxes	1.00	1.00	1.00
Consumer prices net of taxes	-0.17	-0.17	-0.17
Private consumption	-0.53	-0.54	-0.61
Domestic sales	-0.22	-0.18	-0.22
Imports	-0.22	-0.18	-0.22
Gas oil			
Consumer prices gross of taxes	5.07	5.07	5.07
Consumer prices net of taxes	-0.17	-0.17	-0.17
Private consumption	-3.21	-3.23	-3.25
Domestic sales	-0.43	-0.41	-0.29
Imports	-0.43	-0.41	-0.29
Natural gas			
Consumer prices gross of taxes	11.33	11.08	10.87
Consumer prices net of taxes	-1.84	-2.06	-2.24
Private consumption	-6.08	-6.07	-6.05
Domestic sales	-1.40	-1.96	-1.23
Imports	-5.00	-6.00	-5.69

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The drop in the domestic sales of gasoline, gas oil and natural gas leads to a fall in the imports (see table 4.30) and in a decline of the gross output of manufacture of coke and refined petroleum products and production and distribution of gas (see tables 4.31 and 4.32).

Table 4.31. Effects of the policy measure on the manufacture of coke, refined petroleum products and nuclear fuel sector in 2012

Manufacture of coke, refined petroleum products and nuclear fuel	Regions		
	wal	vla	bru
Price of domestic production	-0.15	-0.19	-0.25
Domestic production	-0.31	-0.07	-0.06
Employment	0.08	-0.13	-0.14
Investments	-0.62	-0.59	-0.60
Exports	-0.33	-0.05	0.01

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

Like in the previous scenario the profitability of both manufacture of coke and refined petroleum products and production and distribution of natural gas sectors declines leading to a drop in investments. Employment by the distribution of natural gas sector decreases by more than 1.2 per cent compared with the baseline in 2012 in all the three regions (see tables 4.31 and 4.32).

Table 4.32. Effects of the policy measure on the production and distribution of natural gas in 2012

Production and distribution of natural gas	**Regions**		
	wal	**vla**	**bru**
Price of domestic production	-2.11	-2.13	-1.75
Domestic production	-0.69	-0.69	-0.52
Employment	-1.68	-1.68	-1.27
Investments	-0.75	-0.73	-0.71
Exports	3.70	3.73	3.04

Note: All the variable are reported as percentage change compared with the baseline. The results are provided for 2012 if not indicated otherwise.

The additional tax revenues generated by the policy measure is 337 million euros which would allow a reduction in the personal income tax by 0.87 per cent. The negative impact in terms of real GDP at both the regional and the national level is slightly higher than in the previous scenario (see tables 4.33 and 4.34) due to the relatively larger magnitude of the policy measure.

Table 4.33. Macroeconomic effects of the policy measure

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
GDP (% change)	-0.01	-0.03	-0.04	-0.05	-0.07	-0.08	-0.09	-0.11
National savings (% change)	-0.12	-0.23	-0.34	-0.45	-0.55	-0.64	-0.75	-0.85
Labor supply (% change)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unemployment rate (%)	8.29	8.25	8.27	8.30	8.31	8.32	8.31	8.30
Exchange rate (% change)	-0.02	-0.05	-0.07	-0.09	-0.11	-0.13	-0.15	-0.17
CO2 tax revenues (mil EUR)	41	82	123	165	206	248	292	337
Income tax (% change)	-0.12	-0.24	-0.35	-0.46	-0.57	-0.67	-0.77	-0.87

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

Unemployment rate at both the national and the regional levels rises by about 0.07 percentage points in 2012 compared with the baseline (see tables 4.33 and 4.34).

Table 4.34. Regional effects of the policy measure

		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Labor supply (% change)	**wal**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**vla**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor supply (% change)	**bru**	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Unemployment rate (%)	**wal**	10.90	10.84	10.85	10.88	10.89	10.90	10.91	10.91
Unemployment rate (%)	**vla**	5.58	5.56	5.60	5.65	5.68	5.70	5.68	5.66
Unemployment rate (%)	**bru**	15.81	15.72	15.63	15.56	15.49	15.42	15.40	15.37
Regional GDP (% change)	**wal**	-0.01	-0.03	-0.04	-0.06	-0.07	-0.09	-0.10	-0.12
Regional GDP (% change)	**vla**	-0.01	-0.03	-0.04	-0.05	-0.07	-0.08	-0.09	-0.10
Regional GDP (% change)	**bru**	-0.01	-0.02	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

At the national level the CO2 emissions drop by 1.26 per cent in 2012 compared with the baseline. Again, the highest reduction at regional level, in relative terms, is achieved in Brussels, 2.45 per cent, due to the important share of emissions originating from the residential sector in this region (see table 4.35). At the sectoral level, the most significant CO2 emissions reduction is achieved by the production and distribution of natural gas sector and manufacturing of coke and refined petroleum products (see table 6.69, appendix 3) due to the decline in their output and the consumption of fuels in the production process.

Table 4.35. Effects of the policy measure on the CO2 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CO2 emissions		-0.16	-0.31	-0.47	-0.62	-0.78	-0.96	-1.11	-1.26
National CO2 emissions (kt)		123,054	123,394	124,699	125,967	127,254	127,075	127,188	127,315
Regional CO2 emissions	**wal**	-0.16	-0.32	-0.48	-0.63	-0.79	-0.97	-1.13	-1.28
Regional CO2 emissions	**vla**	-0.14	-0.29	-0.44	-0.58	-0.74	-0.89	-1.04	-1.17
Regional CO2 emissions	**bru**	-0.31	-0.62	-0.93	-1.24	-1.55	-1.87	-2.16	-2.45
Regional CO2 emissions (kt)	**wal**	43,768	44,155	44,884	45,591	46,329	45,592	45,807	46,026
Regional CO2 emissions (kt)	**vla**	75,333	75,233	75,660	76,073	76,467	76,856	76,692	76,536
Regional CO2 emissions (kt)	**bru**	3,953	4,006	4,154	4,303	4,458	4,626	4,689	4,753
Household CO2 emissions	**wal**	-0.58	-1.14	-1.69	-2.23	-2.75	-3.27	-3.77	-4.26
Household CO2 emissions	**vla**	-0.53	-1.04	-1.55	-2.05	-2.54	-3.03	-3.50	-3.96
Household CO2 emissions	**bru**	-0.58	-1.14	-1.70	-2.25	-2.79	-3.33	-3.84	-4.35
Household CO2 emissions (kt)	**wal**	11,547	11,774	12,020	12,277	12,557	12,867	12,924	12,981
Household CO2 emissions (kt)	**vla**	21,218	21,405	21,746	22,100	22,487	22,929	22,848	22,770
Household CO2 emissions (kt)	**bru**	2,266	2,296	2,393	2,492	2,596	2,712	2,744	2,778

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

Similarly to the previous scenario, the decline in the consumption of fuels subject to CO2 tax leads to a reduction of the CH4 emissions and N2O emissions. However, given the important share of process emissions with respect to these two types of greenhouse gases, the overall decline at the national level is small (see tables 4.36 and 4.37) .

Table 4.36. Effects of the policy measure on the CH4 emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National CH4 emissions		0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.05
National CH4 emissions (kt)		7,834	7,757	7,683	7,611	7,542	7,475	7,405	7,337
Regional CH4 emissions	**wal**	-0.01	-0.02	-0.03	-0.04	-0.05	-0.07	-0.08	-0.10
Regional CH4 emissions	**vla**	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
Regional CH4 emissions	**bru**	-0.14	-0.29	-0.44	-0.60	-0.77	-0.95	-1.10	-1.25
Regional CH4 emissions (kt)	**wal**	2,384	2,361	2,338	2,316	2,295	2,275	2,252	2,230
Regional CH4 emissions (kt)	**vla**	5,440	5,387	5,335	5,285	5,236	5,189	5,141	5,095
Regional CH4 emissions (kt)	**bru**	9	9	10	10	11	11	11	11
Household CH4 emissions	**wal**	-0.32	-0.65	-0.98	-1.30	-1.64	-1.97	-2.28	-2.60
Household CH4 emissions	**vla**	-0.31	-0.62	-0.94	-1.26	-1.58	-1.90	-2.21	-2.51
Household CH4 emissions	**bru**	-0.28	-0.56	-0.85	-1.15	-1.46	-1.78	-2.07	-2.35
Household CH4 emissions (kt)	**wal**	57	59	61	63	66	68	70	71
Household CH4 emissions (kt)	**vla**	21	22	23	24	25	26	26	27
Household CH4 emissions (kt)	**bru**	4	4	5	5	5	6	6	6

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

At the national level, CH4 emissions drop by 0.05 per cent in 2012 compared with the baseline, while at the regional level: Brussels achieves the highest reduction in relative terms, 1.25 per cent compared with the baseline, followed by Wallonia with 0.10 per cent and Flanders with 0.02 per cent (see table 4.36). The same pattern is observed in the N2O emissions reduction, however the magnitude of the effects is slightly higher that in the case of CH4 emissions (see table 4.37).

Table 4.37. Effects of the policy measure on the N2O emissions

		2005	2006	2007	2008	2009	2010	2011	2012
National N2O emissions		-0.02	-0.04	-0.06	-0.09	-0.11	-0.14	-0.17	-0.20
National N2O emissions (kt)		11,561	11,444	11,339	11,236	11,139	11,044	10,924	10,808
Regional N2O emissions	**wal**	0.00	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.05
Regional N2O emissions	**vla**	-0.02	-0.05	-0.08	-0.11	-0.14	-0.18	-0.22	-0.25
Regional N2O emissions	**bru**	-0.12	-0.24	-0.38	-0.51	-0.66	-0.81	-0.94	-1.07
Regional N2O emissions (kt)	**wal**	3,757	3,698	3,643	3,589	3,536	3,485	3,429	3,374
Regional N2O emissions (kt)	**vla**	7,700	7,640	7,586	7,533	7,483	7,433	7,368	7,305
Regional N2O emissions (kt)	**bru**	104	105	110	115	120	126	127	129
Household N2O emissions	**wal**	-0.32	-0.65	-0.98	-1.30	-1.64	-1.97	-2.28	-2.60
Household N2O emissions	**vla**	-0.31	-0.62	-0.94	-1.26	-1.58	-1.90	-2.21	-2.51
Household N2O emissions	**bru**	-0.28	-0.56	-0.85	-1.15	-1.46	-1.78	-2.07	-2.35
Household N2O emissions (kt)	**wal**	18	18	19	20	21	21	22	22
Household N2O emissions (kt)	**vla**	475	492	510	530	551	575	585	595
Household N2O emissions (kt)	**bru**	43	44	46	49	52	55	56	56

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

e. The compliance with the voluntary agreements undertaken in Wallonia and Flanders

The fifth policy scenario evaluates the effects of sectoral agreements undertaken in Wallonia and Flanders. The sectors that implemented voluntary agreements in Wallonia and Flanders and their corresponding targets in energy efficiency to be achieved by 2012 are summarized in tables 4.4 and 4.5. For Wallonia, the estimated decrease in the energy consumption is based on a potential reduction of the measure which corresponds to a pay-back period of less than 4 years.

In GreenMod II, the targets established for the increase in the energy efficiency (see tables 4.4 and 4.5) are assumed to be achieved in 2012. During 2003-2012 the targets are increased gradually. The effects of cogeneration have not been taken into account in this scenario.

From the theoretical point of view, voluntary agreements imply multiple effects, some of which can go in opposite directions. In the short-run, the agreements could increase the unit production costs due to the adjustment costs (external or internal). However, the literature shows that the increase is not always significant, and depends on a number of factors such as the legislation, the economic, technological, and institutional context in which the firm (or the sector) is operating (Krarup and Ramesohl, 2002; Linden and Carlsson-Kanyama, 2002; Chidiak, 2002; Grepperud, 2002). Furthermore, these costs are not always linked to the investments induced by the agreement. Krarup and Ramesohl (2002) further suggest that they could have a limited impact on investment criteria and planning related to the investment in energy efficiency technologies unless it is explicitly required, by relaxing the pay-back requirements (e.g. the Danish case).

The studies show that the costs implied by the agreements are marginal, and are mainly driven by factors which are not linked to the agreements. In some cases, the administrative costs linked to the agreements could be high (e.g. the Dutch and the Danish schemes), while in other cases they could be very low (e.g. the Swedish scheme). The Dutch and Danish schemes[21], which are structured and explicitly integrated into the policy mix, imply higher administrative costs due to the necessity of implementing and verifying the energy audits and the monitoring of the energy management plans. The Swedish scheme[22] has very low administrative costs due to the fact that is less structured. Somewhere in between stand the German and the French schemes[23], that can be characterized as non-binding agreements. For the German and the French schemes, the more significant administrative costs occur in the implementation and monitoring stages. Thus, there

[21] Both the Dutch and the Danish schemes are considered as "negotiated agreements".

[22] The Swedish scheme is considered as a "public voluntary programme".

[23] The German scheme is considered as a "unilateral industrial initiative", while the French scheme as "negotiated agreements".

is a big uncertainty about the costs induced by the voluntary agreements in the short-run for both the firms and the public authorities.

On the medium and long term, the voluntary agreements could also have ambiguous effects due to two opposite mechanisms. On one hand, the firms should increase their energy efficiency to reach the target set by the agreements, and therefore lower their energy consumption per unit of output. On the other hand, as the energy efficiency increases, the unit production cost declines, which leads to firms increasing its total production and therefore its total energy consumption. This is furthermore true, when the energy efficiency is a prerequisite in decreasing the fiscal expenditures on the energy per unit of output, like in the Danish scheme[24] (Johansen, 2002). As a result, no certain conclusions can be drawn on the effects of the voluntary agreements on production or employment. The studies on the effects of such arrangements are still sparse. However, Bjorner and Jensen (2002) and Khanna and Damon (1999) suggest that the voluntary agreements tend to have a significant impact in reducing energy consumption. The reduction might be achieved through the increase of the energy efficiency, even when the firm increases its production.

Finally, the effect of the voluntary agreements on the firms' external competitiveness is not always negative. This depends on the efficiency gains that the company can achieve compared to its adjustment costs, and to the changes in the relative prices in the economy. The competitiveness could therefore either improve or worsen. The only way to answer these questions by taking into account the multiple effects is through quantitative analysis.

Simulation results with GreenMod II show that the macroeconomic effects of implementing the voluntary agreements schemes would be positive in the long run: at the national level the real GDP would increase by 0.29 per cent in 2012 compared to the baseline (see table 4.38), while at the regional level the real GDP would increase by 0.29 per cent in Wallonia, and by 0.34 per cent in Flanders (see table 4.39).

Table 4.38. Macroeconomic effects of the implementation of the voluntary agreements (% change compared to the baseline)

	2005	2006	2007	2008	2009	2010	2011	2012
GDP (% change)	0.07	0.13	0.17	0.21	0.23	0.27	0.28	0.29
National savings (% change)	0.06	0.14	0.19	0.23	0.27	0.31	0.32	0.34
Labor supply (% change)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Unemployment rate (%)	8.22	8.13	8.11	8.12	8.12	8.11	8.09	8.07
Exchange rate (% change)	-0.05	-0.10	-0.13	-0.16	-0.18	-0.21	-0.22	-0.23

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

Unemployment rate drops by 0.16 percentage points at the national level in 2012 compared to the baseline, due to the increase in domestic production which leads to an increase employment demand by the sectors. At the regional level, Wallonia achieves a reduction of 0.17 percentage points and Flanders 0.16 percentage points in 2012.

Table 4.39. Regional effects of the implementation of the voluntary agreements (% change compared to the baseline)

		2005	2006	2007	2008	2009	2010	2011	2012
Labor supply (% change)	**wal**	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Labor supply (% change)	**vla**	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Labor supply (% change)	**bru**	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Unemployment rate (%)	**wal**	10.85	10.73	10.70	10.71	10.69	10.68	10.68	10.67
Unemployment rate (%)	**vla**	5.50	5.44	5.44	5.46	5.48	5.48	5.45	5.43
Unemployment rate (%)	**bru**	15.77	15.63	15.51	15.42	15.33	15.25	15.22	15.18
Regional GDP (% change)	**wal**	0.05	0.10	0.14	0.18	0.22	0.25	0.27	0.29
Regional GDP (% change)	**vla**	0.09	0.16	0.21	0.27	0.28	0.33	0.34	0.34
Regional GDP (% change)	**bru**	0.03	0.05	0.07	0.08	0.09	0.09	0.10	0.10

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

[24] The Danish scheme gives access to lower tax rates on CO_2 emissions for the energy-intensive plans joining the agreements.

Table 4.40. Sectoral and regional effects of the voluntary agreements adoption in 2012 (% change compared to the baseline)

Production sectors		**Energy efficiency gains**		**Percentage change in the energy used**		**Price of output**		**Production**		**Exports**		**CO2 emissions**	
		Wal	**Vla**	**Wal**	**Vla**	**Wal**	**Vla**	**Wal**	**Vla**	**Wal**	**Vla**	**Wal**	**Vla**
Manufacture of food products and beverages	**secE6**	6.03	15.25	-5.59	-15.34	-0.28	-0.35	0.24	0.55	0.31	0.71	-5.65	-15.39
Manufacture of pulp, paper and paper products	**secE7**	14.08	11.68	-12.68	-10.99	-0.74	-0.36	1.49	1.44	1.90	1.54	-12.78	-10.99
Manufacture of coke, refined petroleum products and nuclear fuel	**secE8**	5.56	4.92	-4.28	-8.76	-0.25	0.37	-0.79	-6.01	-0.78	-6.52	-4.28	-8.76
Manufacture of chemicals and chemical products	**secE9**	6.67	9.48	-4.34	-7.16	-0.47	-0.45	0.37	0.74	0.53	0.90	-4.23	-7.05
Manufacture of other non-metallic mineral products	**secE10**	4.67	4.43	-2.68	-2.49	-0.25	-0.16	0.21	0.04	0.22	-0.01	-2.73	-2.55
Manufacture of basic metals	**secE11**	5.67	5.00	-1.43	-2.97	-0.33	-0.31	5.55	4.73	5.64	4.80	-1.48	-3.10
Manufacture of fabricated metal products	**secE12**	10.80		-10.53		-0.30		0.75		0.82		-10.54	
Manufacture of machinery and equipment n.e.c.	**secE13**	10.80		-9.20		-0.05		0.21		0.08		-9.18	
Manufacture of motor vehicles, trailers and semi-trailers	**secE18**		7.35		-6.55		-0.16		-0.12		-0.17		-6.53
Manufacture of other transport equipment	**secE19**	10.80		-9.84		-0.24		0.16		0.17		-9.85	
Other manufacturing	**secE20**		2.69		-2.57		-0.15		0.09		0.03		-2.59

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The results are driven by the increase in the energy efficiency in the sectors which signed the voluntary agreements (see table 4.40). The growth in the energy efficiency leads to a decline in the production costs of the sectors combined with a fall in the consumption of energy inputs (see table 4.40). In Brussels, although no voluntary agreements have been implemented, the real GDP increases by 0.10 per cent in 2012 compared to the baseline, due to the positive effects induced by the other two regions through the changes in relative regional prices and import demands. The higher impact on the real GDP in Flanders compared with Wallonia is attained due to the larger efficiency gains in the Flemish region.

The decline in the production costs achieved through the increase in the energy efficiency by the voluntary agreements sectors leads to a decrease in the consumer prices, and therefore to a rise in the private consumption of these products by both household income groups (see tables 6.97 and 6.98, appendix 3). Thus, the gross output of most sectors that implemented voluntary agreements in Wallonia and Flanders goes up (see table 4.40). Consequently, employment in these sectors rises (see table 6.95, appendix 3).

The production of manufacture of coke and refined petroleum products, the production and distribution of natural gas sector and the production and distribution of nuclear and non-nuclear electricity sectors declines due to the reduction in consumption of energy inputs by the sectors that implemented voluntary agreements, which overweight the rise in private consumption (see table 6.94, appendix 3). Subsequently, employment by these sectors diminishes. Overall, the increase in the labor demand by most of the voluntary agreements sectors outbalance the drop in employment by the energy producing sectors and thus unemployment rate at both the national and the regional levels goes down.

The measure also seems to have positive effects in terms of external competitiveness (see table 4.40). In most of the voluntary agreements sectors, the relative decline in the domestic prices compared to the world prices induces a rise in the competitiveness and thus exports increase.

The policy measure has positive effects in terms of regional CO_2 emissions by reducing the consumption of energy inputs and rising energy efficiency in the voluntary agreements sectors (see table 4.41). At the national level, the measure results in a 1.28 per cent reduction of the CO2 emissions in 2012 compared with the baseline. The highest contribution to the CO2 abatement is given by Flanders, with 1.80 per cent cut compared with the baseline.

Table 4.41. Effects of the implementation of the voluntary agreements on the CO2 emissions (% change compared to the baseline)

		2005	2006	2007	2008	2009	2010	2011	2012
National CO2 emissions		-0.30	-0.48	-0.68	-0.90	-0.94	-1.24	-1.27	-1.28
National CO2 emissions (kt)		122,874	123,179	124,433	125,619	127,047	126,708	126,976	127,284
Regional CO2 emissions	**wal**	-0.04	-0.12	-0.23	-0.32	-0.41	-0.51	-0.55	-0.59
Regional CO2 emissions	**vla**	-0.47	-0.73	-0.99	-1.31	-1.34	-1.77	-1.80	-1.80
Regional CO2 emissions	**bru**	0.07	0.15	0.20	0.23	0.26	0.23	0.24	0.27
Regional CO2 emissions (kt)	**wal**	43,822	44,243	44,993	45,735	46,507	45,807	46,075	46,349
Regional CO2 emissions (kt)	**vla**	75,084	74,898	75,238	75,516	76,000	76,176	76,097	76,050
Regional CO2 emissions (kt)	**bru**	3,968	4,037	4,202	4,367	4,540	4,725	4,804	4,885
Household CO2 emissions	**wal**	0.07	0.15	0.20	0.24	0.28	0.27	0.29	0.32
Household CO2 emissions	**vla**	0.11	0.20	0.27	0.32	0.35	0.36	0.37	0.41
Household CO2 emissions	**bru**	0.09	0.18	0.24	0.28	0.31	0.27	0.28	0.32
Household CO2 emissions (kt)	**wal**	11,623	11,927	12,251	12,587	12,948	13,338	13,469	13,602
Household CO2 emissions (kt)	**vla**	21,353	21,674	22,147	22,635	23,154	23,730	23,766	23,807
Household CO2 emissions (kt)	**bru**	2,281	2,327	2,441	2,556	2,679	2,812	2,862	2,913

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The CO_2 emissions by household increase up to 2012 due to their higher income level which stimulates consumption, including the consumption of energy inputs (see tables 6.97 and 6.98, appendix 3). The measure by itself would not be enough to achieve the regional targets established for 2008-2012, moreover the CH4 process emissions slightly rises (see table 4.42).

Table 4.42. Effects of the implementation of the voluntary agreements on the CH4 emissions (% change compared to the baseline)

		2005	2006	2007	2008	2009	2010	2011	2012
National CH4 emissions		0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
National CH4 emissions (kt)		7,835	7,758	7,685	7,614	7,545	7,478	7,409	7,341
Regional CH4 emissions	**wal**	0.00	0.00	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04
Regional CH4 emissions	**vla**	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03
Regional CH4 emissions	**bru**	0.04	0.10	0.12	0.12	0.14	0.05	0.06	0.09
Regional CH4 emissions (kt)	**wal**	2,385	2,361	2,339	2,317	2,296	2,276	2,253	2,232
Regional CH4 emissions (kt)	**vla**	5,441	5,388	5,337	5,287	5,238	5,191	5,144	5,098
Regional CH4 emissions (kt)	**bru**	9	9	10	10	11	11	11	12
Household CH4 emissions	**wal**	0.06	0.12	0.16	0.19	0.22	0.19	0.20	0.23
Household CH4 emissions	**vla**	0.08	0.15	0.19	0.22	0.25	0.22	0.24	0.27
Household CH4 emissions	**bru**	0.06	0.12	0.16	0.16	0.19	0.08	0.10	0.14
Household CH4 emissions (kt)	**wal**	57	60	62	64	67	70	71	73
Household CH4 emissions (kt)	**vla**	21	22	23	24	25	26	27	27
Household CH4 emissions (kt)	**bru**	4	4	5	5	5	6	6	6

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

With regard to the N20 emissions, the decrease by 0.60 per cent in 2012 at the national level is mainly achieved by the Flemish region (see table 4.43).

Table 4.43. Effects of the implementation of the voluntary agreements on the N2O emissions (% change compared to the baseline)

		2005	2006	2007	2008	2009	2010	2011	2012
National N2O emissions		-0.11	-0.14	-0.21	-0.34	-0.35	-0.57	-0.60	-0.60
National N2O emissions (kt)		11,550	11,433	11,322	11,208	11,112	10,996	10,876	10,765
Regional N2O emissions	**wal**	0.01	0.02	0.03	0.02	0.02	0.00	0.00	0.00
Regional N2O emissions	**vla**	-0.17	-0.22	-0.33	-0.51	-0.54	-0.85	-0.89	-0.88
Regional N2O emissions	**bru**	0.02	0.05	0.06	0.04	0.05	-0.05	-0.04	-0.02
Regional N2O emissions (kt)	**wal**	3,758	3,700	3,645	3,590	3,538	3,486	3,430	3,376
Regional N2O emissions (kt)	**vla**	7,689	7,627	7,567	7,503	7,454	7,384	7,318	7,259
Regional N2O emissions (kt)	**bru**	104	106	110	115	121	127	128	130
Household N2O emissions	**wal**	0.06	0.12	0.16	0.19	0.22	0.19	0.20	0.23
Household N2O emissions	**vla**	0.08	0.15	0.19	0.22	0.25	0.22	0.24	0.27
Household N2O emissions	**bru**	0.06	0.12	0.16	0.16	0.19	0.08	0.10	0.14
Household N2O emissions (kt)	**wal**	18	19	19	20	21	22	22	23
Household N2O emissions (kt)	**vla**	476	496	516	538	561	588	599	612
Household N2O emissions (kt)	**bru**	43	44	47	50	53	56	57	58

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

5. Conclusion

Following the approval of the Kyoto Protocol by the European Union and the Burden Sharing Agreement among the member states, the *regional* impacts of various burden sharing formulas have been a major political and economic concern in Belgium. The Walloon and the Flemish governments have already introduced voluntary agreement schemes with major energy intensive sectors and the European Emission Trading System has been launched in January 2005. Some other policy measures are currently under discussion.
The only quantitative tool capable of producing results at the sectoral and regional level for Belgium is the dynamic regional and sectoral general equilibrium model GreenMod II. In this study, we use the model to evaluate the effects of:

- A tax of €10 per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households) - Simulation I;
- A tax of €20 per ton of CO2 emissions generated by the consumption of gasoline and gas oil for transportation (firms and households) - Simulation II;
- A tax of €10 per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households - Simulation III;
- A tax of €20 per ton of CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households - Simulation IV;
- The compliance with the voluntary agreements undertaken in Wallonia and Flanders - Simulation V.

The effects of policy measures on the greenhouse gases emissions at national and regional levels are summarized in table 4.44.
The introduction of a CO2 tax on emissions generated by the consumption of gasoline and gas oil for transportation (firms and households) leads to a rather limited effect on the greenhouse gases emissions. The €20 tax per ton of CO2 emissions (simulation II) generates a reduction of 0.54 per cent of GHG emissions in 2012 compared with the baseline, which represents about 798 thousand tonnes. Also the effects on GHG emissions of the introduction of a CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households are limited in size. The €20 tax per ton of CO2 emissions (simulation IV) leads to a drop of 1.12 per cent of GHG emissions in 2012 compared with the baseline, equivalent to 1.65 million tonnes. The highest reduction in the GHG emissions is achieved by the implementation of the voluntary agreements with the major energy intensive sectors in Wallonia and Flanders, 1.17 per cent in 2012 compared with the baseline, which represents about 1.72 million tonnes. Thus, the emissions reduction targets set by the Kyoto Protocol cannot be reached by implementing the measures examined above.

Table 4.44. Effects of the policy measures on the GHG emissions

		1990	2005	2006	2007	2008	2009	2010	2011	2012	Distance from Kyoto target
BAU scenario											
National GHG emissions (kt)		138,880	142,643	142,985	144,314	145,616	146,954	146,841	146,965	147,110	18,647
Regional GHG emissions (kt)	**wal**	52,234	49,980	50,356	51,081	51,787	52,530	51,802	52,013	52,230	3,914
Regional GHG emissions (kt)	**vla**	82,659	88,584	88,483	88,919	89,346	89,764	90,186	90,020	89,866	11,505
Regional GHG emissions (kt)	**bru**	3,987	4,079	4,146	4,314	4,483	4,660	4,852	4,932	5,014	892
Simulation I											
National GHG emissions			-0.03	-0.07	-0.10	-0.13	-0.17	-0.21	-0.24	-0.27	
National GHG emissions (kt)		138,880	142,596	142,888	144,168	145,420	146,705	146,536	146,611	146,706	18,242
Regional GHG emissions	**wal**		-0.04	-0.08	-0.12	-0.17	-0.20	-0.25	-0.29	-0.33	
Regional GHG emissions	**vla**		-0.03	-0.06	-0.09	-0.12	-0.15	-0.18	-0.21	-0.24	
Regional GHG emissions	**bru**		-0.04	-0.07	-0.11	-0.15	-0.19	-0.23	-0.26	-0.30	
Regional GHG emissions (kt)	**wal**	52,234	49,960	50,314	51,017	51,702	52,422	51,674	51,863	52,058	3,741
Regional GHG emissions (kt)	**vla**	82,659	88,559	88,432	88,842	89,242	89,631	90,021	89,828	89,649	11,288
Regional GHG emissions (kt)	**bru**	3,987	4,077	4,143	4,309	4,476	4,651	4,841	4,920	4,999	877
Simulation II											
National GHG emissions			-0.07	-0.13	-0.20	-0.27	-0.34	-0.41	-0.48	-0.54	
National GHG emissions (kt)		138,880	142,549	142,793	144,024	145,226	146,459	146,238	146,264	146,312	17,848
Regional GHG emissions	**wal**		-0.08	-0.17	-0.25	-0.33	-0.41	-0.49	-0.57	-0.65	
Regional GHG emissions	**vla**		-0.06	-0.11	-0.17	-0.23	-0.29	-0.36	-0.42	-0.48	
Regional GHG emissions	**bru**		-0.07	-0.15	-0.22	-0.29	-0.37	-0.45	-0.52	-0.59	
Regional GHG emissions (kt)	**wal**	52,234	49,939	50,272	50,954	51,618	52,317	51,549	51,716	51,891	3,574
Regional GHG emissions (kt)	**vla**	82,659	88,534	88,381	88,765	89,139	89,500	89,859	89,641	89,437	11,076
Regional GHG emissions (kt)	**bru**	3,987	4,076	4,140	4,304	4,469	4,643	4,831	4,907	4,985	862
Simulation III											
National GHG emissions			-0.07	-0.14	-0.21	-0.28	-0.36	-0.44	-0.52	-0.59	
National GHG emissions (kt)		138,880	142,545	142,786	144,010	145,202	146,424	146,188	146,202	146,236	17,772
Regional GHG emissions	**wal**		-0.07	-0.14	-0.22	-0.29	-0.37	-0.46	-0.53	-0.61	
Regional GHG emissions	**vla**		-0.06	-0.13	-0.19	-0.26	-0.33	-0.41	-0.48	-0.55	
Regional GHG emissions	**bru**		-0.16	-0.31	-0.47	-0.63	-0.79	-0.96	-1.12	-1.27	
Regional GHG emissions (kt)	**wal**	52,234	49,945	50,283	50,970	51,636	52,337	51,565	51,735	51,910	3,594
Regional GHG emissions (kt)	**vla**	82,659	88,528	88,370	88,746	89,111	89,464	89,817	89,589	89,375	11,014
Regional GHG emissions (kt)	**bru**	3,987	4,072	4,133	4,293	4,454	4,623	4,806	4,877	4,950	828
Simulation IV											
National GHG emissions			-0.14	-0.27	-0.41	-0.55	-0.69	-0.85	-0.99	-1.12	
National GHG emissions (kt)		138,880	142,449	142,595	143,721	144,815	145,935	145,594	145,516	145,460	16,997
Regional GHG emissions	**wal**		-0.14	-0.28	-0.42	-0.56	-0.70	-0.87	-1.01	-1.15	
Regional GHG emissions	**vla**		-0.13	-0.25	-0.38	-0.51	-0.64	-0.78	-0.91	-1.03	
Regional GHG emissions	**bru**		-0.31	-0.61	-0.92	-1.22	-1.53	-1.84	-2.13	-2.41	
Regional GHG emissions (kt)	**wal**	52,234	49,910	50,214	50,865	51,496	52,160	51,352	51,488	51,630	3,314
Regional GHG emissions (kt)	**vla**	82,659	88,474	88,261	88,582	88,891	89,186	89,479	89,201	88,936	10,576
Regional GHG emissions (kt)	**bru**	3,987	4,066	4,121	4,274	4,428	4,589	4,763	4,828	4,893	771
Simulation V											
National GHG emissions			-0.27	-0.43	-0.61	-0.81	-0.85	-1.13	-1.16	-1.17	
National GHG emissions (kt)		138,880	142,259	142,369	143,440	144,441	145,704	145,183	145,261	145,390	16,926
Regional GHG emissions	**wal**		-0.03	-0.10	-0.20	-0.28	-0.36	-0.45	-0.49	-0.53	
Regional GHG emissions	**vla**		-0.42	-0.64	-0.87	-1.16	-1.20	-1.59	-1.62	-1.62	
Regional GHG emissions	**bru**		0.07	0.15	0.20	0.23	0.25	0.22	0.23	0.26	
Regional GHG emissions (kt)	**wal**	52,234	49,964	50,304	50,977	51,642	52,340	51,569	51,758	51,956	3,639
Regional GHG emissions (kt)	**vla**	82,659	88,214	87,913	88,141	88,306	88,691	88,751	88,559	88,407	10,046
Regional GHG emissions (kt)	**bru**	3,987	4,081	4,152	4,322	4,493	4,672	4,863	4,944	5,027	905

Note: If not indicated otherwise, all the variable are reported as percentage change compared with the baseline.

The simulation results show that the tax policy measures (first four scenarios) would have a small negative impact on the real GDP and employment. The first household income group achieves welfare gains in the first two policy scenarios (simulation I and II) mainly due to the increase in the transfers[25] from the regional and federal governments (see table 4.45). The second household income group experiences welfare losses in Wallonia and Flanders due to the drop in the labour income. Labour income represents about 60 per cent of the total income of the second household income group. In Brussels, the negative effect on welfare corresponding to the second household income group is reversed due to the slight increase in the capital income which outbalances the decline in the labour income. The share of the capital income in Brussels for the second income group is higher (17.3 per cent) compared to Flanders (10.0 per cent) and Wallonia (8.0 per cent). The effect on the capital income is induced by the recycling scheme, which leads to a decline in the corporate income tax.

[25] The first group includes the low income households.

With regard to the tax on CO2 emissions generated by the consumption of coal, gasoline, gas oil and natural gas for heating and transportation by the households (simulation III and IV), the first income group experiences welfare losses due to the higher share of consumption of coal, gas oil and natural gas for heating in their consumption budget.

The adoption of the voluntary agreements with the major energy intensive sectors in Wallonia and Flanders would have positive economic effects, in terms of energy efficiency, energy consumption, economic growth and employment. Moreover, both income groups would experience welfare gains in the fifth policy scenario due to the increase in the capital and labour income. (see table 4.45).

Table 4.45. Effects of the policy measures on the households' welfare

Equivalent variation (mil EUR)		2005	2006	2007	2008	2009	2010	2011	2012
Simulation I									
First households' income group	**wal**	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04
First households' income group	**vla**	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04
First households' income group	**bru**	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04
Second households' income group	**wal**	-0.02	-0.04	-0.06	-0.08	-0.11	-0.13	-0.15	-0.17
Second households' income group	**vla**	-0.04	-0.09	-0.14	-0.19	-0.24	-0.29	-0.35	-0.41
Second households' income group	**bru**	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.04
Simulation II									
First households' income group	**wal**	0.01	0.02	0.03	0.04	0.05	0.05	0.07	0.08
First households' income group	**vla**	0.02	0.03	0.04	0.05	0.05	0.06	0.06	0.07
First households' income group	**bru**	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.08
Second households' income group	**wal**	-0.04	-0.08	-0.12	-0.17	-0.21	-0.26	-0.30	-0.35
Second households' income group	**vla**	-0.08	-0.18	-0.28	-0.38	-0.48	-0.58	-0.70	-0.81
Second households' income group	**bru**	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07
Simulation III									
First households' income group	**wal**	-0.01	-0.02	-0.03	-0.05	-0.07	-0.09	-0.10	-0.11
First households' income group	**vla**	-0.01	-0.02	-0.03	-0.05	-0.07	-0.10	-0.12	-0.14
First households' income group	**bru**	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.04	-0.05
Second households' income group	**wal**	0.08	0.15	0.21	0.28	0.34	0.40	0.48	0.56
Second households' income group	**vla**	0.14	0.26	0.38	0.49	0.60	0.71	0.84	0.97
Second households' income group	**bru**	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
Simulation IV									
First households' income group	**wal**	-0.02	-0.04	-0.07	-0.10	-0.13	-0.16	-0.18	-0.21
First households' income group	**vla**	-0.01	-0.03	-0.06	-0.09	-0.14	-0.19	-0.22	-0.26
First households' income group	**bru**	-0.01	-0.02	-0.03	-0.05	-0.06	-0.07	-0.09	-0.10
Second households' income group	**wal**	0.15	0.29	0.42	0.55	0.67	0.79	0.95	1.10
Second households' income group	**vla**	0.27	0.52	0.75	0.97	1.18	1.38	1.63	1.89
Second households' income group	**bru**	0.02	0.05	0.06	0.08	0.10	0.11	0.14	0.16
Simulation V									
First households' income group	**wal**	0.03	0.08	0.12	0.15	0.18	0.20	0.21	0.24
First households' income group	**vla**	0.01	0.16	0.24	0.30	0.46	0.61	0.65	0.72
First households' income group	**bru**	0.03	0.07	0.09	0.11	0.13	0.14	0.15	0.16
Second households' income group	**wal**	0.38	0.77	1.07	1.35	1.56	1.76	1.85	1.98
Second households' income group	**vla**	1.28	2.05	2.80	3.57	3.80	4.58	4.82	5.01
Second households' income group	**bru**	0.13	0.26	0.36	0.45	0.51	0.56	0.59	0.62

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6. Appendix:

6.1. Classification of the production sectors and commodities in GreenMod II:

NACE code	Name of the production sector or commodity	Commodity code in GreenMod II	Production sector code in GreenMod II
1	Agriculture, hunting and related service activities	comE1	secE1
2	Forestry, logging and related service activities	comE2	secE2
5	Fishing, operation of fish hatcheries and fish farms	comE3	secE3
10	Mining of coal and lignite; extraction of peat	comE4	secE4
11	Extraction of crude petroleum and natural gas; incidental service activities		
	Extraction of natural gas	comE5	secE5
	Extraction of crude petrolium	comE6	secE6
12	Mining of uranium and thorium ores	comE7	secE7
13	Mining of metal ores	comE8	secE8
14	Other mining and quarrying	comE9	secE9
15	Manufacture of food products and beverages	comE10	secE10
16	Manufacture of tobacco products	comE11	secE11
17	Manufacture of textiles	comE12	secE12
18	Manufacture of wearing apparel; dressing and dyeing of fur	comE13	secE13
19	Tanning and dressing of leather	comE14	secE14
20	Manufacture of wood and of products of wood and cork	comE15	secE15
21	Manufacture of pulp, paper and paper products	comE16	secE16
22	Publishing, printing and reproduction of recorded media	comE17	secE17
23	Manufacture of coke, refined petroleum products and nuclear fuel		secE18
	Coke oven coke	comE18	
	Petroleum coke	comE19	
	Nuclear energy	comE20	
	Gasoline	comE21	
	Heavy oil	comE22	
	Gas oil	comE23	
	Coke oven gas	comE24	
	Refinery gas	comE25	
	Other combustibles	comE26	
24	Manufacture of chemicals and chemical products	comE27	secE19
25	Manufacture of rubber and plastic products	comE28	secE20

NACE code	Name of the production sector or commodity	Commodity code in GreenMod II	Production sector code in GreenMod II
26	Manufacture of other non-metallic mineral products	comE29	secE21
27	Manufacture of basic metals	comE30	secE22
28	Manufacture of fabricated metal products	comE31	secE23
29	Manufacture of machinery and equipment n.e.c.	comE32	secE24
30	Manufacture of office machinery and computers	comE33	secE25
31	Manufacture of electrical machinery and apparatus n.e.c.	comE34	secE26
32	Manufacture of radio, television and communication equipment and apparatus	comE35	secE27
33	Manufacture of medical, precision and optical instruments, watches and clocks	comE36	secE28
34	Manufacture of motor vehicles, trailers and semi-trailers	comE37	secE29
35	Manufacture of other transport equipment	comE38	secE30
36	Manufacture of furniture; manufacturing n.e.c.	comE39	secE31
37	Recycling	comE40	secE32
40	Electricity, gas, steam and hot water supply		
	Production and distribution of natural gas	comE41	secE33
	Production and distribution of electricity	comE42*	secE34
	Collection, purification and distribution of water		secE35
41	Construction	comE43	secE36
45	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	comE44	secE37
50	Wholesale trade and commission trade, except of motor vehicles and motorcycles	comE45	secE38
51	Retail trade, except of motor vehicles and motorcycles	comE46	secE39
52	Hotels and restaurants	comE47	secE40
55	Land transport; transport via pipelines	comE48	secE41
60	Water transport	comE49	secE42
61	Air transport	comE50	secE43
62	Supporting and auxiliary transport activities; activities of travel agencies	comE51	secE44
63	Post and telecommunications	comE52	secE45
64	Financial intermediation, except insurance and pension funding	comE53	secE46
65	Manufacture of fabricated metal products	comE54	secE47
66	Insurance and pension funding	comE55	secE48
67	Activities auxiliary to financial intermediation	comE56	secE49
70	Real estate activities	comE57	secE50
71	Renting of machinery and equipment without operator	comE58	secE51

NACE code	Name of the production sector or commodity	Commodity code in GreenMod II	Production sector code in GreenMod II
72	Computer and related activities	comE59	secE52
73	Research and development	comE60	secE53
74	Other business activities	comE61	secE54
75	Public administration and defence; compulsory social security	comE62	secE55
80	Education	comE63	secE56
85	Health and social work	comE64	secE57
90	Sewage and refuse disposal, sanitation and similar activities	comE65	secE58
91	Activities of membership organization n.e.c.	comE66	secE59
92	Recreational, cultural and sporting activities	comE67	secE60
93	Other service activities	comE68	secE61
95	Private households with employed persons	comE69	secE62

Table 4.46. Aggregated version of GreenMod II used for the policy simulations

NACE code	Name of the production sector or commodity	Commodity code in GreenMod	Production sector code in GreenMod
1, 2, 5	Agriculture, forestry, fishing	ComE1	SecE1
10	Mining of coal and lignite; extraction of peat	ComE2	secE2
11	Extraction of crude petroleum and natural gas; incidental service activities		
	Extraction of natural gas	ComE3	SecE3
	Extraction of crude petroleum	ComE4	SecE4
12, 13, 14	Mining of uranium and thorium ores; mining of metal ores; other mining and quarrying	ComE5	SecE5
15	Manufacture of food products and beverages	ComE6	SecE6
21	Manufacture of pulp, paper and paper products	ComE7	SecE7
23	Manufacture of coke, refined petroleum products and nuclear fuel		SecE8
	Coke oven coke	ComE8	
	Petroleum coke	ComE9	
	Nuclear energy	ComE10	
	Gasoline	ComE11	
	Heavy oil	ComE12	
	Gas oil	ComE13	
	Coke oven gas	ComE14	
	Refinery gas	ComE15	
	Other combustibles	ComE16	
24	Manufacture of chemicals and chemical products	ComE17	SecE9
26	Manufacture of other non-metallic mineral products	ComE18	SecE10
27	Manufacture of basic metals	ComE19	SecE11
28	Manufacture of fabricated metal products	ComE20	SecE12
29	Manufacture of machinery and equipment n.e.c.	ComE21	SecE13
30	Manufacture of office machinery and computers	ComE22	SecE14
31	Manufacture of electrical machinery and apparatus n.e.c.	ComE23	SecE15
32	Manufacture of radio, television and communication equipment and apparatus	ComE24	SecE16
33	Manufacture of medical, precision and optical instruments, watches and clocks	ComE25	SecE17
34	Manufacture of motor vehicles, trailers and semi-trailers	ComE26	SecE18
35	Manufacture of other transport equipment	ComE27	SecE19
16-20, 22, 25, 36, 37	Other manufacturing	ComE28	SecE20

NACE code	Name of the production sector or commodity	Commodity code in GreenMod	Production sector code in GreenMod
40	Electricity, gas, steam and hot water supply		
	Production and distribution of natural gas	ComE29	SecE21
	Production and distribution of nuclear electricity	ComE30*	SecE22
	Production and distribution of non-nuclear electricity		SecE23
60, 61	Land transport; water transport; transport via pipelines	ComE31	SecE24
62	Air transport	ComE32	SecE25
63	Supporting and auxiliary transport activities; activities of travel agencies	ComE33	SecE26
75	Public administration and defence; compulsory social security	ComE34	SecE27
80	Education	ComE35	SecE28
85	Health and social work	ComE36	SecE29
41, 45, 50-52, 55, 64-67, 70-74, 90-93, 95	Other services	ComE37	SecE30

SPSD II (2000-2005)

BELGIAN SCIENCE POLICY

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SPSD II

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