A CGE MODEL FOR ENVIRONMENTAL AND TRADE POLICY ANALYSIS IN CHILE: CASE STUDY FOR FUEL TAX INCREASES

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Abstract

Computable General Equilibrium (CGE) models are a powerful economic tool for multidimensional/multi-sectoral analysis. They improve traditional input-output analysis generating quantities and prices endogenously and reflecting market incentives. They complement partial equilibrium analysis with a broader scope of analysis and the quantification of indirect and often non-intuitive effects. Environmental applications of CGE models include trade and environment, climate change, energy problems, natural resources management and environmental regulation analysis. The ECOGEM-Chile model described in this paper can be used to analyse impacts on macro, sectoral, social and environmental (air, water and land pollutants) variables of different economic, social or/and environmental policies, such as trade policies, environmental taxes, external price shocks, among others. The model incorporates the recently released 1996 input/output matrix as well as the most recent information on wages and income. In the specific application developed here, the model is used to analyse direct and indirect impacts on the Chilean economy of increasing fuel taxes by 100%. Additionally a trade policy of reducing tariffs to compensate the increase in revenues of these taxes is simulated. The tariff reductions are in line with the current Chilean trade policy. Winners and loser from both exercises are identified as well as the main determinants of the results.

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1. Introduction

Achieving economic growth has been important issue for over half a century. More recently developed countries have incorporated the need of a more equitative and environmentally balanced growth. Considering the complexity of modeling an economy with all its interrelations, agents and sectors, common practice has lead to the study of the economic, social and environmental policies in isolated form, in a context of partial equilibrium. Unfortunately, many measures that affect, for example the environment, also impact economic growth, poverty, employment or income distribution. Thus, to understand fully the effects of either macroeconomic policies on the environment or the impact of environmental or welfare policies on the macroeconomic variables it is necessary to use models that include the complex interrelations between the diverse sectors and agents of the economy. In this half-century there have been significant developments in the concepts and more fundamentally in the analytic and computational tools, that allow implementing such models.

During the sixties, growth and more generally economic development, was the central objective of the "economic planning". In 1966, Kuznets emphasized that in order to reach modern economic growth and the so called industrialization of the developing countries, it would be necessary to introduce drastic and systematic changes in the productive structures along with changes in the demand, employment, investment and international trade. Also, he warned of the relevance of examining carefully the velocity and schedule for these changes. Accordingly, planning in depth the process of growth, with a relevant level of detail and disaggregation, was deemed fundamental.

The systematic and structural nature of the intended economic changes, and the great speed with which these were applied, generated consequences that revealed crudely that the productive sectors, the trade structures, the different markets and their participating agents could not be considered, analyzed or intervened independently. Productive bottlenecks, excesses in sectoral supply, unsatisfied demand, inefficient resource allocation, in addition to the dependence of national policies and their structural adjustments to international events, increased the necessity to develop multi-sectoral models with increasing disaggregation. These were required to provide a useful framework to understand and to plan the structural changes, stressing the interrelations and interdependencies among productive sectors, markets, agents, etc., in a setting of general equilibrium.

In this context, input-output models were initially the main tools for those in charge of economic planning. They allowed the analysis of the linkages between sectors, the use of productive factors, mainly capital and labor. They also were helpful in understanding the different components of the final demand, the value added of each particular sector, and to compare them in a systematic basis.

However, these models suffer from serious limitations such as their inability to incorporate market mechanisms and processes of optimization, their fixed coefficients which impose fixed relative prices, their poor substitution possibilities and the lack of social and environmental variables. Nevertheless, they were used for these purposes, taking advantage of the incipient development of computer sciences and mathematical techniques.

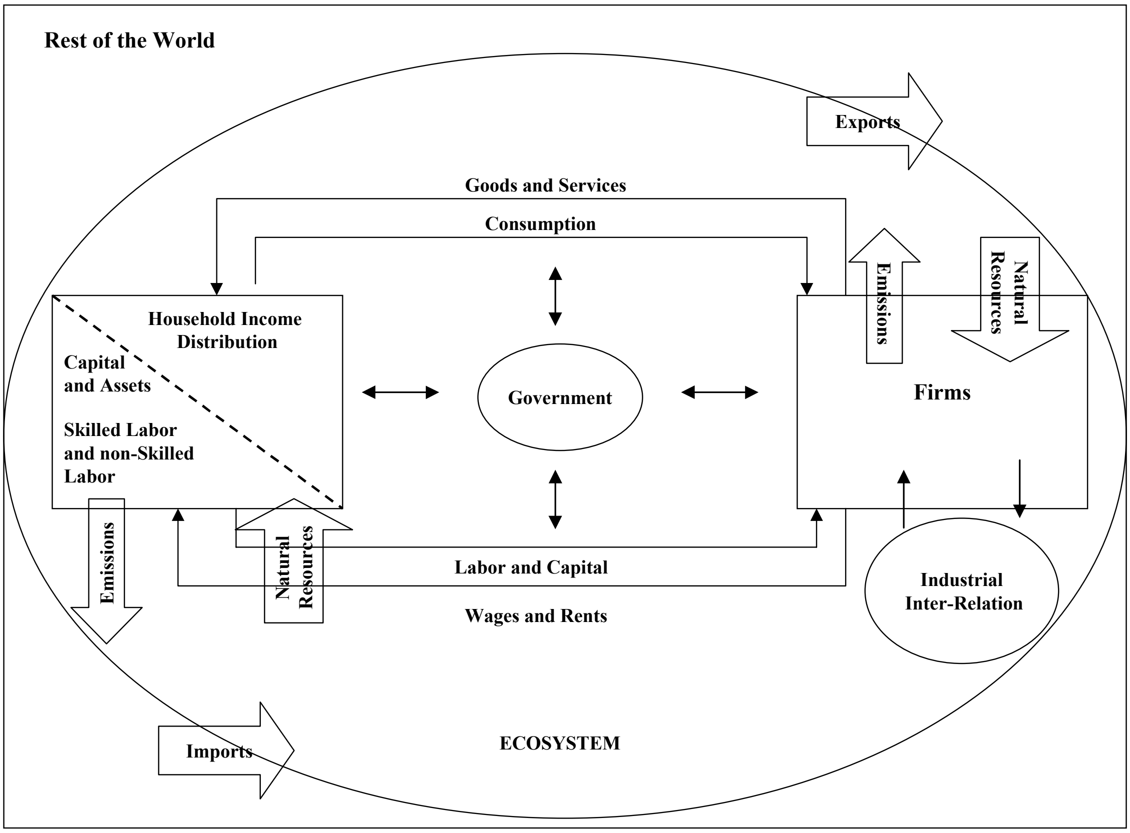
In the seventies, exclusive concern about growth and development goals began to be perceived as insufficient. The debate about the need to balance economic growth and environmental impacts entered strongly starting in 1972 when the Club of Rome published "Limits to Growth" (Meadows et. al. 1972). Those in charge of generating social and economic policies and the economic agents in general had to prepare for the incorporation of new relevant variables into their decision process. The models of growth increased their complexity and the detailed definition of development strategies became even more necessary.

In 1987 the Brundtland Commission incorporated the concept of "sustainable development" into the mainstream discussion, defining it rather vaguely as development that "allows achieving the needs of the present generations without endangering the future generations". In practice, this definition has required that in developing society meet simultaneously economic, environmental and social objectives both for the present as well as for future generations (Pearce and Turner 1990). As a result, at present countrywide economic models need to take into account a diversity of objectives associated to sustainable development. The economic objectives consider the need for economic growth, as well as more equity and efficiency. The environmental objectives include concern about systems integrity, bio-diversity, and capacity of assimilation and global topics. Finally, the social objectives include issues in participation, social mobility, cultural identity, and institutional development, among others. From then on, debate over development has continued with more or less conflicting positions, incorporating and trying to integrate in the most appropriate way the economic and environmental variables (The Economist 1997, Dasgupta and Mäler 1998, Kneese 1998).

Increasingly the complexity of the direct and indirect interrelations among economic, environmental and social variables has called for models that allow evaluating policies which lead to sustainability. At the same time, these models must take into account market mechanisms and optimizing behaviors, which determine the decisions of the economic agents and the effectiveness of public policies. The prevailing economic paradigm, not particularly prone to "planning" processes, requires eliminating the shortcomings of input-output models when failing to incorporate market mechanisms.

Consequently increasingly sophisticated policy analysis tools have been developed. These models have become able to capture the complex concept of sustainability, analyzing systematically and quantitatively the evolution of the variables related to its three macro-objectives (economic growth, equity and environmental sustainability). In particular, since the late seventies and especially in the eighties, applications based on computable general equilibrium models (CGE) were developed. These multi-sectoral models solve the limitations of the input-output models as evaluation instruments, representing in a more realistic way the economy of a country by incorporating market mechanisms in the assignment of resources. Also, they have proved to be a useful instrument to describe the main relationships outlined, and to evaluate quantitatively *ex-ante* the effects of different policies, economic, social or environmental, in addition to the indirect side effects which in many cases evade the intuition.

Figure 1 Economy circular flow



Source: Own elaboration.

Figure 1 presents schematically the relationships that can be modeled by means of a CGE, based on the circular flow of the economy. It includes the main agents (firms, households, and government), flows of goods and services, payments to factors, international trade and relationships with the environment. Each agent is modeled according to certain behavior assumptions; in particular it is common to assume optimizing producers (cost) and consumers (utility). Additionally, each market is modeled according to the specific reality of the economy, for instance as a competitive or non-competitive market, or in the case of the labor market, with or without full employment.

These models simulate an economic Walrasian equilibrium by equating demand and supply in all markets, obtaining equilibrium prices and quantities. A fundamental characteristic of the productive sector in these models, as in the input-output models is that it incorporate the

demand for intermediate inputs, not just capital and labor. However, they differ from the rigid cost structure of the input-output models by allowing cost minimization by economic agents through substitution among production inputs (type and origin). Additionally, the government sector is also modeled as an agent that applies taxes, subsidies and transfers[1];
Finally, CGE models can be both static and dynamic. Static models are normally used for analyzing the interrelations throughout the economy and the linkages between sectors and different agents. Moreover, they focus on stabilization policies and contingency issues. Dynamic models focus more on forecasting issues related to growth patterns and development strategies. Nevertheless, by altering parameters and elasticities static models can deal with different temporal frameworks. There are tradeoffs between analysis and forecasting. Good analysis can be done using many sectors, but also many assumptions and large amounts of parameters are required. Alternatively, with many sectors it is hard to make realistic forecast estimations in a dynamic framework, and simpler models are preferred.

The goal of this paper is to show the potential of CGE analysis as a tool for policy evaluation in Chile. In order to achieve this the paper is organized as follows. Section 2 presents the basic features, assumptions and equations of the ECOGEM-Chile model. Next, section 3 shows the data used for simulating with the model. Section 4 presents the economic, social and environmental impacts resulting from an increment of fuel taxes by 100%. A trade policy is analyzed in this section by simulating the impact of reducing tariffs to compensate the increase in public revenues. Finally, section 5 presents the main conclusions.

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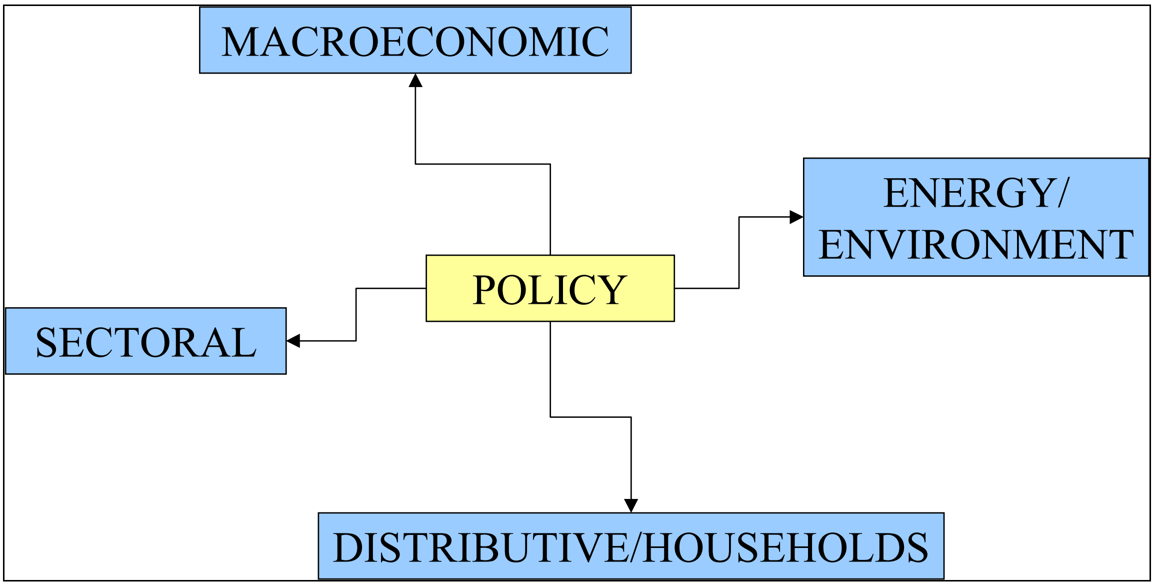
[1] Generally, CGE models do not include endogenous optimizing behavior or any objective function for the public sector. Technical and ethical reasons can be mentioned. Regarding the first, the budget restriction, including both expenditures/transfers and tax revenues, is the principal component of the policy simulations and it is modified exogenously to explore different policy implications. It is also a key element for the domestic closure rules of the model. On the other hand, tax structure and the distribution of the expenditures (coming from the social accounting matrix) already represent an elected government decision, which must symbolize the preference of the majority of voters in a democracy. Finally, if modeling a public utility function, which allows to endogenously modify the public expenditure decisions in response to, let's say, an external shock, this function must be supported by an ethical discussions and by the generally accepted economic thinking in order to endorse the empirical results of the simulations.

2. The ECOGEM-Chile Model

The ECOGEM-Chile model has been developed to analyze, in a general equilibrium framework, different policies and their impacts over the various agents in the economy. To this end we describe the ECOGEM-Chile model as a model capable of analyzing, the impacts of a given economic, social or environmental policy on macroeconomic, sectoral and social variables and the environment (Figure 2).

Figure 2: ECOGEM-Chile Analysis



2.1.- Basic Features of the ECOGEM-Chile

The CGE model developed for Chile is a static model with multiple sectors, labor differentiation, income-groups differentiation, trade partners, and specified productive factors, among other features.[2] It is a neoclassical model, which is savings-driven. It incorporates energy-input substitution to reduce emissions because the emissions are related to the use of different inputs as well as to production and consumption levels, which is the common way to deal with.

[2] The model presented herein, ECOGEM-Chile, has been developed by INAP and CEA/DII of the University of Chile, based on the one generated at the OECD by Beghin, Dessus, Roland-Holst and van der Mensbrugghe (1996).

The most important equations of the model are presented in this section, particularly those associated to environmental variables. The main indexes that will be used in the model's equations are listed below:

i, j	Productive sectors or activities
l	Types of work or occupational categories
h	Household income groups (quintiles)
g	Public spending categories
f	Final demand spending categories
r	Trade partners
p	Different types of pollutants

2.1.1 Production Structure:

Production is modeled by the CES/CET nested functions (i.e. constant elasticity of substitution – transformation). If constant returns to scale are assumed, each sector produces while minimizing costs[3]:

$$\min \; PKEL_i KEL_i + PND_i ND_i$$

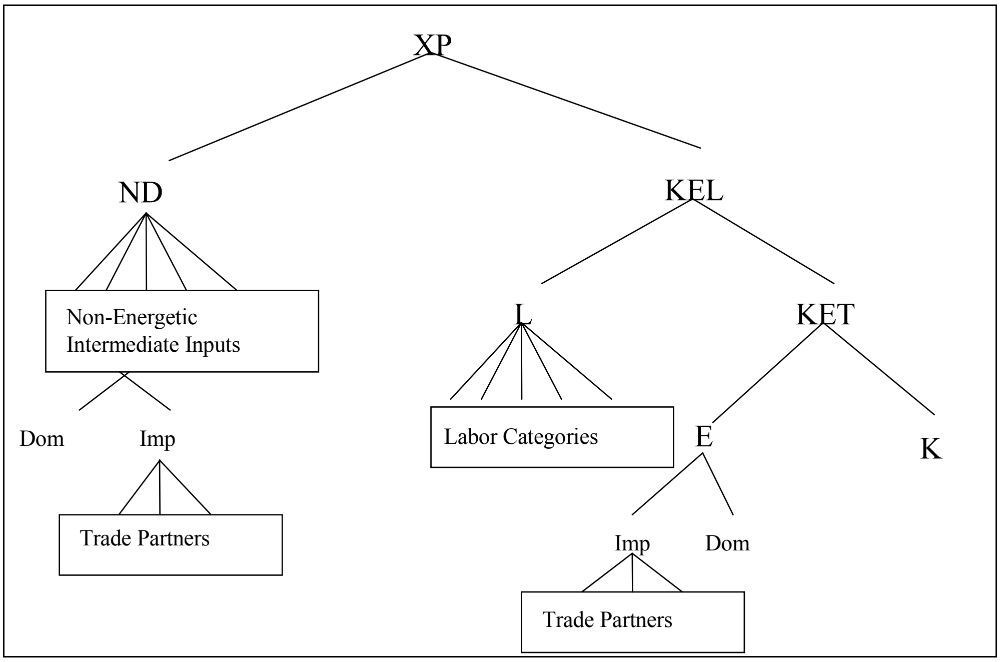
$$\text{s.t.}$$

$$XP_i = \left[\alpha_{kel,i} KEL_i^{\sigma_i^p} + \alpha_{nd,i} ND_i^{\sigma_i^p}\right]^{1/\sigma_i^p}$$

Figure 3 presents the production function as a nested input/factors tree. In the tree's first level, decisions are made through a CES function to choose from a non-energy-producing intermediate input basket and a factor basket (i.e. capital and labor) and energy producing inputs (KEL). In order to obtain the non-energy-producing intermediate input basket a Leontieff-type function is assumed. On the factor side, the capital-energy basket and labor is split through a new CES function, and then energy is separated from capital, always assuming CES functions for substitution both between and within factors (types of labor, energy, and capital). Energy was modeled as a third factor in order to allow substitution between energy inputs, therefore allowing sectors to adjust more realistically to environmental policies related to air emissions.

[3] A full glossary of terms can be found in Annex A.

Figure 3: CES-nested Production Function



Source: Beghin, et. al. (1996)

2.1.2 Consumption:

Households use their income for consumption and savings. Their decision process is modeled by an ELES utility function (Extended Linear Expenditure System)[4]. This function also incorporates a minimum subsistence consumption independent from the level of income.

$$\max \ U = \sum_{i=1}^{n} \mu_i ln(C_i - \theta_i) + \mu_s \ ln\left(\frac{S}{cpi}\right)$$

$$\text{subject to } \sum_{i=1}^{n} PC_i C_i + S = YD$$

$$\text{and } \sum_{i=1}^{n} \mu_i + \mu_s = 1$$

[4] The way in which savings are included (divided by a price index of the other goods) partially neutralizes the substitution between consumption and savings, because the savings` price is a weighted price of all the other goods. In this sense, savings represent future consumption.

Where U stands for the consumer's utility; C_i is the consumption of good i; θ is the subsistence consumption; S, saving; *cpi*, the price of savings; and μ the consumption marginal propensity for each good and to save.

2.1.3 Other Final demands:

Apart from intermediate demands and household demands, the model includes the rest of final demand: investment, government consumption and trade margins. These demands are modeled through fixed shares of the total final demand.

2.1.4 Public Finances:

The model also considers different types of taxes and transfers. The following direct taxes are defined in the model: labor tax (differentiated by occupational category), taxes on firms, on income (differentiated by quintile). Import tariffs and subsidies are defined, as well as export taxes and subsidies (by sector). Value added tax VAT (for domestic and imported goods, and by sector) and specific taxes are also included.

2.1.5 Foreign sector:

To incorporate the foreign sector, the Armington assumption is used to break down goods by place of origin, allowing imperfect substitution between domestic and imported goods and services. As with production, there is a CES function that allows substitution between the imported and the domestic basket. In turn, the domestic supply gets a similar treatment as demand, now including a CET function to distinguish between domestic market from exports.

For imports:

$$\min\ PD{\cdot}XD + PM\cdot XM$$

$$\text{subject to}\quad XA = \left[\alpha_d XD^{\sigma} + \alpha_m XM^{\sigma}\right]^{1/\sigma}$$

where *PD* and *PM* are the prices of domestic and imported goods, while *XD* and *XM* are the respective amounts. *XA* stands for the good made up of both, i.e., the "Armington good". Parameter ρ is the substitution elasticity between both goods.

For exports:

$$\max\ PD{\cdot}XD + PE{\cdot}ES$$

$$\text{subject to}\quad XP = \left[\gamma_d XD + \gamma_e ES^{\lambda}\right]^{1/\lambda}$$

where *PE* is the price of the exported good and *ES* is the respective amount. *XP* is the sector's total production. Parameter λ is the substitution elasticity between both goods.

2.1.6 Factor Market Equilibrium Conditions:

In order to achieve labor market equilibrium, labor supply and demand are made equal for each occupational category, where supply is determined on the basis of real wages. As for the capital market, a single type of capital is assumed to exist, which may or may not have sector mobility depending in the imposed elasticity.

2.1.7 Closure Conditions:

As a closure condition for public finances, the model allows two alternatives: first, government savings are defined as fixed and equal to the original level previous to any simulation, allowing adjustment through some tax or government transfer in order to achieve government fiscal target. Second, government savings are allowed to vary, while taxes and transfers are kept fixed. The second option was chosen in the application developed in this paper.

Also, as is usual in these models, the value of the demand for private investment must equal the economy's net aggregate saving (from firms, households, government and net flows from abroad). The last closing rule refers to balance of payment equilibrium. This equation will be introduced into the model through Walras Law.

2.2.- Environmental Specifications in the Model

The model allows three possibilities to reduce emissions of pollutants in the economy. They all come from introducing some kind of tax or policy that alters the economic players' decisions in their profit or benefit maximizing processes. The first, most traditional and common one in general equilibrium models, is the reduction in the production of the very pollutant sectors. The second is the substitution between different energy inputs that may be more or less polluting. The third possibility is determined by the ability to reduce emissions by the use of "end of pipe" technologies (e.g. filters, treatment plants). This latter possibility is in its experimental stage and will not be included in the results of our simulations.

Not included in the model is the possibility of technological change –from investment processes based on relative returns– towards new less polluting technologies, because it would be necessary to use a dynamic model. Moreover it is currently possible to change substitution elasticities to simulate more flexible technologies to less polluting processes. Also left out of the players' utility function is the environmental quality as a good for which there is a willingness to pay, and therefore alters consumption decisions on the rest of the goods and their equilibrium prices.

A. Production Reduction: In this case, introducing a tax on emissions generates an increase in production costs which in turn causes -*ceteris paribus*- an increase in the price of the good produced by the polluting industry (that pays for the tax). Thus it becomes less competitive at both the national and international level and reduces the amount demanded for the good and also production, at least in the long run. In case of an environmental regulation that sets a limit for emissions, the company will be forced to reduce its level of production.

Basically, this possibility comes from making prices endogenous in the general equilibrium model and the possibility of reallocating factors and resources among the various productive sectors, substitution between different goods for final demand or substitution between the domestic and the foreign markets (CES/ELES/CET-Armington functions, respectively).

B Substitution between inputs: the use of each type of input in either the production or the consumption by final demand causes a certain level of emissions independently of the productive process. Therefore, another way to reduce emissions is to substitute less polluting inputs for the more polluting ones. In case of a tax on emissions, the costs associated to the use of that input are being indirectly increased, and thus their relative use is being made costlier and its substitution encouraged.

In case a new emission regulation is set, a constraint is introduced to optimization both in the domestic economies and in firms. In this case, to continue using the same volume of polluting inputs leads to a below-optimal situation that converges towards the original optimum to the extent that substitution occurs towards less or non-contaminating inputs.

The model basically differentiates between energy-producing and non energy-producing inputs. Non energy-producing ones are used in the production function with fixed coefficients. Substitution between energy-producing inputs or between these and other productive factors (capital and labor) is determined by CES functions nested within the production function.

Energy-producing inputs (i.e. coal, petrogas, petroref, electricity, and gas) are associated to the emission of up to 13 types of pollutants (not all of them discharged by the energy-producing inputs) through emission factors. Said emission factors link the use of each money unit spent in the input the amount of emissions of each pollutant in physical units.

Total volume of emissions in the economy for each type of pollutant is therefore determined by:

$$E_p = \sum_i \upsilon_i^p \cdot XP_i + \sum_i \pi_i^p \cdot \left(\sum_j XAp_{ij} + \sum_h C_{ih} + \sum_f XAFD_f^i \right)$$

that is, by the sum of all the emissions of the pollutant "*p*" caused by all the productive sectors "*i,j*" of the input-output matrix (74 sectors for Chile) generated in their productive processes *per se*, independently of the emissions associated to the use of polluting inputs, in addition to all the emissions derived from the use of polluting intermediate inputs[5] in the productive processes of all the sectors, in their consumption by households "*h*" and by other components of the final demand "*f*".

2.3. Further development in the ECOGEM-Model

The model presented can be improved in many directions to allow a more complete analysis of policy options. Some specific improvements are discussed below.

A. The dynamic version

In order to include dynamics in the model there are two possibilities: (i) a new dynamic forward looking model or (ii) a recursive-dynamic model based on the static ECOGEM-Chile model. Using the ECOGEM-Chile model it is possible to solve the model for several stages (periods) and link them through the capital accumulation equation. In this sense investment in period T becomes capital stock for period T+1. Capital is then assigned among sectors according to the relative rates of return. For the calibration, a baseline scenario for the growth path is required, which usually is called business as usual scenario. Population, labor force, depreciation and GDP growth rates are exogenous and type of technical process should be chosen (capital/labor efficiency ratio). If alternative scenarios

[5] Not only energy-producing.

to the base line are simulated, the technical efficiency parameter becomes constant and the capital growth is endogenously determined by the saving/investment relation.

B. Abatement possibilities

In order to incorporate the reduction in emissions through new end-of-pipe technologies it is necessary to include a new productive sector that, when used by the other sectors allows to reduce the sector's emissions. This sector then becomes the abatement technology sector[6]. For this, a CES function must be included that allows substitution between the abatement sector and the rest of the intermediate, non energy-producing-input sectors. The result will be reflected on the following equations:

$$AB_j = \alpha_{AB\,j} \cdot \left[\frac{P_{ABND\,j}}{P_{AB\,j}} \right]^{\sigma^j_{ABND}} \cdot ABND_j$$

$$ND_j = \alpha_{ND\,j} \cdot \left[\frac{P_{ABND\,j}}{P_{ND\,j}} \right]^{\sigma^j_{ABND}} \cdot ABND_j$$

$$P_{ABND\,j} = \left[\alpha_{AB_j} \cdot \left(P_{AB\,j} \right)^{1-\sigma^j_{ABND}} + \alpha_{ND_j} \cdot \left(P_{ND\,j} \right)^{1-\sigma^l_{ABND}} \right]^{\frac{1}{1-\sigma^j_{ABND}}}$$

where AB stands for the abatement expenditure, ND is the expense in the rest of non-energy-producing inputs, and ABND is the nest that includes both. Parameters α_{AB} and α_{ND} are the fractions used of each input, and σ_{ABND} is the substitution elasticity between both inputs. P_{AB}, P_{ND}, and P_{ABND} stand for the respective prices of each input and the price of the compounded input.

Total emissions in the economy will now be also determined by the existing expense in abatement. The coefficients that determine emissions are now weighted by the reduction factor associated to the abatement technologies used:

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[6] Abatement technology is the current expenditure in technology to comply with some green regulation or to avoid paying some environmental tax.

$$E_p = \sum_i \upsilon_i^{*p} \cdot XP_i + \sum_j \sum_i \pi_i^{*p} \cdot X_{ij} + \sum_i \pi_i^p \left(\sum_h XAc_{ih} + \sum_f XAFD_f^i \right)$$

Where for each sector and each pollutant:

$$\pi^* = \pi - \left(\frac{G_{AB}}{\theta} \right)^{\frac{1}{\omega}} \cdot \frac{1}{\sum_i X_{ij}}$$

$$\upsilon^* = \upsilon \cdot \frac{\pi^*}{\pi}$$

where G_{AB} is the sector's expenditure in abatement technologies, X_{ij} is sector j's intermediate demand for sector i, and θ and ω are parameters from the emission cost reduction functions, while υ and π are the emission coefficients associated to the production and use of intermediate inputs, respectively.

To introduce this mechanism in the model it is necessary to disaggregate the data for the abatement sector, and to figure out parameters θ and ω for each sector. Finally, it is necessary to create their market. The demand will then be made up of the sum of the demands of each and every sector in the input-output matrix, while the supply will be determined by a new sector generated from the sectors that produce the abatement technologies, or by a proportion thereof.

C. Environmental Quality in the Utility Function

Individuals experience damage from emissions and they value the environmental quality. Therefore, to fully represent individuals' behavior and preferences, the environmental quality should be incorporated in the utility function. It allows us to endogenously assess the real costs and benefits of an environmental (or other) policy and to obtain the final welfare when agents are able to choose among "traditional" goods and services and environmental ones.

Although there is a large literature on the valuation of environmental damages, there are a very small number of CGE models incorporating endogenously the environmental valuation (C. Perroni & R. Wigle (1994, 1997), M. Tsigas, D. Gray, T. Hertel, B. Krissoff (1999)) and there is not direct estimation of key parameters. The relationship between emissions experienced and environmental damage is modeled by a damage function. Current environmental quality is equal to the difference between endowments of environmental quality and damage. Thus, the individuals' valuation of environmental quality depends on the level of environmental quality and on the consumption of other goods and services. A CES utility function can model the decisions between the environmental quality and the consumption nest (which in turn was modeled by the ELES utility function). The elasticity of substitution should be related to the income elasticity of the environmental quality valuation; the degree of responsiveness of the marginal valuation of environmental quality to an increase in damage depends on the size of the environmental quality endowments. Estimation of parameters and data on environmental quality is required in this area of development. It should be pointed out that, while an environmental utility function is not included in the CGE model, results do not consider benefits from environmental quality improvements, therefore the cost of any environmental policy is overestimated. On the other hand, benefits from economic policies are also overestimated when environmental damage increases.

3. The data

A very important component of any general equilibrium model is the data used. This data includes information for the base year, usually an Input-Output matrix or a Social Accounting matrix, and substitution and income elasticities for each sector. Elasticities can be estimated through econometric regressions if enough information is available or other previous data can be used if the information is not available. The data requirements and number of parameters used make it necessary to be very careful as to the quality of the information used and it requires constant updating.

3.1 Economic Data

As in any general equilibrium model applied, the main source of information is the social accounting matrix (SAM). The matrix for Chile was built based on the 1996 input-output matrix provided by the Central Bank (Central Bank, 2001). The 1996 SAM is the most recent available information for Chile and was developed by de Miguel et. al. (2002), based on the methodology applied by Alonso and Roland-Holst (1995). Data from official surveys on social variables, labor and consumption were used as well as foreign trade information provided by the Central Bank. This SAM has 73 sectors, 20 labor categories (10 rural and 10 urban), 10 groups of income (divided by deciles) and 28 trade regions.

The social accounting matrix for Chile, was aggregated in order to enable a better mathematical convergence for the model. In the simulation exercise presented on chapter 4, the SAM includes 18 economic sectors[7]; labor is divided into skilled and unskilled; it includes the foreign sector without origin differentiation and disaggregates household income into five quintiles. The matrix is measured in billions of pesos of 1996 purchasing power, although in this type of exercise, measure units and amounts are not so relevant as are the variables' ratio accuracy (relative weight).

The model allows varying income, substitution and other elasticities to model realistically the timing of the adjustment process. Therefore, it is possible to choose short, medium or long-term elasticities used in the relevant international literature, providing different degrees of flexibility according with the objective of the policy exercises. However, as this is a static model, capital accumulation processes as a function of relative returns are not included. Inter-sectoral capital mobility and long-term substitution elasticities only may minimize this flaw.

[7] The specific sectors are described in Annex B.

3.2 Emission Factors

For the Chilean case, the input-output matrix sectors considered in the set of energy-producing inputs are:

- Production of Oil and Natural Gas (PetrGas): *A priori*, it considers the extraction of petroleum and natural gas in their mining phase.
- Coal Mining
- Oil refinery (PetrRef): this sector groups all the production of heavy petroleum, gasoline and kerosene.
- Electricity
- Gas: Gas production and distribution.

There are two types of emission coefficients, input based and related to output. The first relate emissions to the use of polluting "goods" that generate emissions, e.g. Coal, Gas, Oil products, etc. The second type of coefficients relates emissions to the total output of each sector. Among the 13 types of pollutants (air, water and land) with available emission coefficients, we have selected for the simulations those related to the air pollution problem in Santiago. These are: SO2, NO2, VOC (volatile organic compounds), CO and Suspended Particulates.

The emission factors associated to output are obtained independently of the inputs used by each sector. To extrapolate the data to Chile the national SAM figures were used, thereby obtaining the levels of emissions on the basis of the valued amount of the inputs used[8].

3.3 Further Developments in Data

Land and water emissions: The model also has included land and water emission factors. Despite this, these have not been included at this point. Further research is needed to include these for Chile, and to adapt them to the local features.

[8] To examine the procedure followed to calculate emissions, together with the estimations' results, see Dessus, Roland-Holst, van der Mensbrugghe (1994).

Abatement sector and technologies: In order to include the abatement technologies it is necessary to include a new sector, the abatement sector. Furthermore, it is also necessary to build cost of abatement curves to be able to model the reductions due to the use of these end of pipe technologies. To this extent both issues have been developed but not yet calibrated in the model, with the new 1996 SAM.

4.- Policy Simulations:

4.1.- A simple exercise increasing fuel taxes[9]

The objective of this section is to show the potentialities of the model by analyzing a specific policy. In this case, we have chosen a restrictive tax policy in order to increase fuel (oil refinery products) taxes to the double of the current tax rate (100% increase). It is assumed that the revenues obtained from this tax policy are not recycled, so government savings are increased[10]. New public saving are channeled to the market increasing liquidity for investment. This policy can be seen as an environmental policy in which contaminating fuels are taxed in order to reduce emissions. For this simulation no capital mobility is allowed and substitution elasticities[11] are quite flexible, therefore sectoral adjustment will tend to be inside the sector (factor/inputs) instead of between sectors[12]. Consequently the results will reflect a short to medium run response to the shocks.

Several impacts can be identified in this scenario. These will be divided according to different criteria. First of all Table 1 shows the main macroeconomic effect of increasing fuel taxes.

[9] Results here presented do not pretend to be real and useful for policy application, they just pretend to show the possibilities of the model. Real applications require a deep analysis and study from the authors.
[10] Other options are possible also. For example the revenue can be used to offset another inefficient tax, which is modeled in section 4.2.
[11] The elasticities used in the present simulation are similar to those assumed by other studies for Chile (Coeymans and Larraín, 1994; Beghin, et. al., 2002; Harrison, et. al., 2002). Additionally in another paper (O`Ryan, et. al., 2003), a sensitivity analysis using the same model is undertaken to show differences when assuming other elasticities in the model.
[12] The same simulation but assuming full capital mobility across sectors is presented in Annex C.

Table 1: Macroeconomic Impacts[13]

Variable	Impact
Production	-1.0%
Consumption	-1.0%
Investment	0.5%
Exports	-1.6%
Imports	-1.5%
Real GDP	-0.5%
Absorption	-0.5%
Real Gov. Savings	11.4%
Corporate Savings	-0.9%

The main effects observed relate to a decrease of basically all macro variables (except investment), due to higher fuel prices in the economy. As Chile is not an Oil Producer, we can observe important effects on Production, Consumption, Imports and Exports. Real GDP is also negatively affected due to the former. It should be pointed out that capital immobility triggers rougher adjustment because intersectoral reallocations are impeded, therefore restricted equilibrium is achieved where macro-effects are enhanced. However, the growth of investment due to the boost of government savings, reduces the overall impact in half. Government savings increase in over 10%, going from roughly 2.5% to 2.75% of GDP.

Sectoral impacts are maybe the most significant in the model. We can identify "winners" and "losers" of each policy. In this case Table 2 shows the impacts on sectoral output, employment, exports and imports. The sectors that are negatively affected are those in extraction or refinery of oil products as well as the transport-related sectors, which directly depend on oil. On the other hand, electricity and coal, substitute energy and now relatively cheaper, appear as "winners", increasing their output. The construction sector also appears as a "winner". This is due to the higher level of investment observed, which has its origin in the increase in public savings. Employment (labor demand) by sector follows the same path as production, increasing when output grows and decreasing otherwise.

[13] All tables are presented in percentages of change.

The rest of the sectors, mainly primary and industrial, also have minor negative effects on their output leading to an overall reduction in the economy's production. The main reason is the increase in production costs due to higher energy costs. This also causes a decrease in wages, as some employment posts are cut. Finally this reduces the households' income as shown later on.

Table 2: Sectoral Effects

Sectors	Production	Labor	Exports	Imports
Renewables	-1.0%	-0.3%	-2.5%	0.4%
Non Renewables	-0.8%	-0.5%	-1.0%	-0.4%
Oil and Gas Extraction	-11.5%	-14.0%	-14.3%	-29.2%
Coal	2.1%	3.7%	-3.0%	5.3%
Food	-0.6%	-0.2%	-1.0%	-0.2%
Textiles	0.0%	0.3%	0.0%	-0.1%
Wood	-0.9%	-0.7%	-1.4%	-0.2%
Chemicals	-0.5%	0.0%	-0.8%	-0.3%
Oil Refinery	-26.8%	-31.8%	-67.4%	6.3%
Machinery	-0.1%	0.3%	-0.3%	0.0%
Electricity	0.6%	3.2%	N/A	3.6%
Gas	-1.2%	1.6%	N/A	N/A
Hydraulic	-0.1%	0.3%	0.5%	-0.3%
Construction	0.4%	1.2%	N/A	0.8%
Commerce	-0.5%	-0.3%	-0.6%	-0.4%
Load and Passenger Transport	-3.6%	0.1%	-15.7%	0.9%
Other Transport	-3.5%	-2.8%	-4.8%	-1.3%
Services	-0.1%	0.2%	0.7%	-0.3%

Imports and exports also vary for each sector. The greatest effects also appear as it should be expected on the most affected sectors. Most sectors reduce both their imports and exports. However some imports are increased due to lower production costs elsewhere. The overall effect is a reduction in trade activity, which is reflected in a decrease if both total imports and total exports (Table 1).

All households are negatively affected. In terms of income and prices the effect on all groups of income is roughly the same (see Table 3). The real income falls almost 1%. However, the effects on welfare may vary. If the level of utility is used to measure the effects on welfare, the poorest groups are more negatively affected than the groups with a higher income. This is due to the definition of the utility function, which considers a decreasing marginal utility, and the impact of the taxation on the minimum subsistence consumption (heating, transportation, etc.) have higher relative impact on poorer consumption baskets.

Table 3: Impacts on Households and welfare

		Impact			**Impact**
Real Income	Quintile I	-1.0%	Prices	Quintile I	0.4%
	Quintile II	-1.0%		Quintile II	0.4%
	Quintile III	-1.0%		Quintile III	0.4%
	Quintile IV	-1.0%		Quintile IV	0.4%
	Quintile V	-0.9%		Quintile V	0.4%
Income	Quintile I	-0.6%	Utility	Quintile I	-1.0%
	Quintile II	-0.6%		Quintile II	-1.0%
	Quintile III	-0.6%		Quintile III	-0.9%
	Quintile IV	-0.6%		Quintile IV	-0.8%
	Quintile V	-0.6%		Quintile V	-0.4%

Finally, we can observe the environmental effects of increasing fuel taxes. Clearly increasing fuel taxes has a basic positive effect on emissions, since emission levels of all pollutants are reduced (Table 4). One of the main pollution problems in Chile are PM10 emissions in Santiago. With this policy they are reduced in over 15%. SO2 and NO2 emissions are also reduced in an important amount, 17% each. CO and VOCs show a lower decrease in total emissions.

Table 4: Environmental Effects

Pollutant	% of change
SO2	-17.3%
NO2	-17.0%
CO	-5.9%
VOC	-2.9%
PM10	-15.8%

4.2.- Increase in fuel taxes that finances a tariff reduction.

The model also allows combining different policies. In the following simulation the government applies a tax substitution: the same increase in fuel taxes is modeled, but now the revenues are channeled to finance tariff reductions. Therefore, government savings remains constant at the initial level. We have now two policies: an environmental policy linked towards fuel taxation and a policy that reduces trade barriers[14].

This exercise follows the same technical characteristics and assumption than the simulation presented in section 4.1. Results are also presented in the same way to facilitate comparisons.

Table 5: Macroeconomic Impacts

Macro-variable	Impact
Production	-0.9%
Consumption	-0.6%
Investment	0.1%
Exports	-0.7%
Imports	-0.6%
Real GDP	-0.4%
Absorption	-0.4%
Real Gov. Savings	0.0%
Corporate Savings	-0.2%
Tariffs revenues	-14.5%

[14] Different fiscal policies can be simulated policies when government wants to maintain public revenues in case of tariff reductions link to free trade policies. Here, fuel tax is presented, but VAT, specific taxation, income taxation, transfers/subsidies, etc. can also be explored and compared.

In this case macro-variables are less affected by the rise in fuel taxation. The decrease of tariffs partially compensates the recessive effect of the environmental taxation by encouraging trade and reducing prices of imported goods and services for production and consumption. In this case public savings remain constant, since revenues from fuel taxation are used to compensate shrinking revenues from tariffs. Aggregate corporate savings experience a small impact, although at a sectoral level in there are strong differences that depend on fuel-use intensities and trade orientation. Aggregate savings remain almost constant, therefore investment. Revenues from tariffs drop by roughly 15%.

Table 6: Sectoral Effects

Sectors	Production	Labor	Exports	Imports
Renewables	-0.7%	0.0%	-1.6%	2.3%
Non Renewables	-0.5%	0.1%	-0.5%	1.2%
Oil and Gas Extraction	-11.7%	-14.6%	-12.2%	-28.1%
Coal	1.5%	2.6%	-1.2%	7.3%
Food	-0.3%	0.1%	0.0%	2.0%
Textiles	0.1%	0.4%	1.8%	1.3%
Wood	-0.6%	-0.3%	-0.5%	1.7%
Chemicals	-0.4%	-0.2%	1.0%	0.9%
Oil Refinery	-26.0%	-31.6%	-65.7%	10.1%
Machinery	-0.1%	0.0%	2.3%	0.5%
Electricity	0.7%	2.9%	N/A	3.1%
Gas	-0.7%	1.6%	N/A	N/A
Hydraulic	0.0%	0.3%	1.5%	-0.4%
Construction	0.1%	0.5%	N/A	-0.3%
Commerce	-0.4%	-0.2%	0.5%	-0.7%
Load and Passenger Transport	-3.2%	0.2%	-13.5%	0.7%
Other Transport	-2.7%	-1.8%	-3.6%	-1.0%
Services	0.0%	0.2%	1.4%	-0.5%

At a sectoral level, there are still fuel-tax effects, however most sectors improve their situation regarding the simulation presented in section 4.1. In fact most negative results regarding exports, imports and employment switch to positive. Production also benefits from tariff reductions. Finally, local energy production (oil and gas extraction and coal) is reduced further since it is bought abroad due to lower tariffs, and construction suffers since investment does not increase in this case.

Table 7: Impacts on Households and welfare

		Impact			Impact
Real Income	Quintile I	-0.7%	Prices	Quintile I	0.1%
	Quintile II	-0.6%		Quintile II	0.0%
	Quintile III	-0.6%		Quintile III	0.1%
	Quintile IV	-0.6%		Quintile IV	0.1%
	Quintile V	-0.6%		Quintile V	0.0%
Income	Quintile I	-0.6%	Utility	Quintile I	-0.7%
	Quintile II	-0.6%		Quintile II	-0.6%
	Quintile III	-0.6%		Quintile III	-0.6%
	Quintile IV	-0.6%		Quintile IV	-0.5%
	Quintile V	-0.6%		Quintile V	-0.3%

Table 7 shows the negative impact on all households. Nevertheless, the price-effect is now smaller and, therefore, both utility and real income improve in relation with our previous simulation. The regressive effect still remains. Positive environmental effects slightly decrease by around one percentage point (table 8).

Table 8: Environmental Effects

Pollutant	% of change
SO2	-16.0%
NO2	-15.7%
CO	-4.4%
VOC	-2.5%
PM10	-14.5%

In summary, the simulated environmental-trade mix policy seems to have more benefits: environmental effects continue but macro and social impacts are smoother. At a sectoral level “winners” and “losers” depend on fuel-use intensity and relation with foreign markets.

5. Conclusions

This paper presents an empirical application of the computable general equilibrium ECOGEM-Chile. The model is very flexible and comprehensive and permits analyzing the impact of policies and external shocks on different agents of the economy. In particular,. It includes detailed sectoral (72), labor (20), trade partner (27), and household (10) disagregations. It incorporates energy-input substitution possibilities and input based emissions of up to 13 different pollutants. The model can analyze impacts on macroeconomic, sectoral, social and environmental variables. Consequently ECOGEM-Chile is a useful tool to analyze policies and external shocks that may affect the most important economic agents in Chile.

To illustrate some of the models features, the impact of an increase in fuel taxes in 100% has been simulated. The results of this simulation show some negative impacts on aggregate variables such as consumption, production, trade and GDP. Sectoral impacts are analyzed and winning and losing sectors are identified. We have assumed that government expenditure does not vary, hence public savings are boosted. The latter generates an increase in investment, which offsets in part the fall in GDP.

Results also show the “winners” and “losers” of this policy. The former are those sectors that provide alternative energy products, i.e. electricity (mainly hydropower) and coal, and construction due to the higher levels of investment. The loser sectors identified are the oil extraction and production as well as the transport sector. Other sectors are also affected, mainly negatively, but in lesser amounts.

Households are also negatively affected, in part by an increase in domestic prices, and in part by a lower income. The latter comes from sectors cutting down workers thus reducing the average wage. All households are affected by the same rate. Finally we observe the positive impacts related to an important emission reduction of all pollutants, which reaches 17% in the case of SO_2 and NO_2 and 15% in the case of PM10 emissions. The environmental benefits were not valued and thus the impact on economic welfare is uncertain.

On the other hand, a mix of environmental and trade policies were also simulated to show the benefits from policy coordination and to discuss alternative closure rules. Here, real public savings remains constant, and all revenues from fuel taxation are compensated by equivalent reductions in trade tariffs. Sectors suffer now from two shocks: increase in fuel taxes and a reduction of tariffs. The results show that most impacts on macro, social and environmental variables smooth down, therefore achieving better average results. These results depend on sector's energy patter and relation to external trade.

It should be noted that no capital mobility was allowed in both of the simulations presented, therefore results represent a medium/short term adjustment. With capital mobility, capital flows from less to more profitable sectors sectoral impacts increase as discussed in section 4.1. Additionally, reduction in other taxes could have been simulated (VAT, Corporate taxes, etc) as well as a reallocation of the increase in public revenues to subsidies/transfers or public expenditure. The model has ample flexibility for this.

The main aim of this paper is to show the potentiality of a general equilibrium analysis, and for this reason the results should not be seen as conclusive for future fuel tax or trade policies. Actually the model results should always be considered as only part of any policy analysis that generally also requires an in depth examination of the results obtained by sectoral specialists. Several improvements may be done in order to enhance the model's capabilities for environmental analysis (dynamic version, abatement technologies and environmental utility function), as well as the integration of natural gas as an important energy input in Chile's economy, especially after 1997, which is not include in the 1996 input-output matrix. Despite these limitations, the present core model consider most economic features of the CGE literature, it has a huge level of economic detail and data desegregation and includes useful environmental/energy characteristics.

Finally, the results show that the model is very useful for analyzing systematically and holistically different policies and their impact on Chile's economy. The model can evaluate trade policies, tax reforms, social and environmental policies, external price shocks and other policies and their impacts on each income group, the different productive sectors and also aggregate impacts.

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ANNEX A: Glossary of Variables and Parameters in the Model

Variable o parameter	**Meaning**
α	Shares of use of inputs/factors
σ	Substitution elasticities
μ	Marginal expenditure and savings propensity
θ	Subsistence minima consumption
λ	CET transformation elasticity
π	Input Based Emission Coeficients
υ	Output Based Emission Coeficients
AB	Abatement Good
ABND	Composite Good of Non energy intermediate inputs and abatement
C	Household Consumption
cpi	Consumers Price Index
E	Emissions
ES	Exported Good
GAB	Abatement Expenditure
KEL	Composite Good of Capital-Energy-Labor
ND	Composite Good of Non energy intermediate inputs
PAB	Price of Abatement good
PABND	Price of the Non Energy intermediate inputs bundle and abatement
PC	Price of the consumption goods
PD	Domestic Price
PE	Exports Price
PKEL	Price of the Capital-Energy-Labor Bundle
PM	Imports Price
PND	Price of the Non Energy intermediate inputs bundle
S	Households' savings
XA	Armington Composite Good
XAFD	Other Total Final Demands (Investment, Government Consumption)
XAp	Intermediate Consumption
XD	Domestic Good
XM	Imported Good
XP	Total Output
YD	Household disposable income

ANNEX B: Sectors Used

Sectors	Reference to 1996 I/O Matrix	Description
Renewables	1-5	Agriculture, Fruit, Livestock, Forestry, Fisheries
Non Renewables	8-10	Copper, Iron, Other Minerals
Oil & Gas Extraction	7	Extraction of Oil and Gas
Coal	6	Coal
Food Ind.	11-25	Slaughter, Diary, Conserves, Sea Food, Oils, Bakery, Mill Products, Sugar, Other Foods, Feedstock, Drinks, Wine, Liquors, Beers, Tobacco
Textiles	26-29	Textile, Clothes, Leather, Shoes
Wood Prods.	30, 31, 46	Wood Products, Furniture, Pulp and Paper
Chemicals	32, 34-38	Printing, Chemicals, Other Chemicals, Rubber, Plastics, Glass
Oil Refinery	33	Refinery
Manufactures	39-45,47	Non metallic minerals, Basic Metals of Iron and steel, Basic Metals of non ferrous metals, Metal mechanics, Non Electric Machinery, Electric machinery, Transport Materials, other manufactures
Electricity	48	Electricity
Gas	49	Gas
Hydraulic	50	Hydraulic
Construction	51	Construction
Commerce	52-54	Commerce, Restaurants, Hotels
Road Transport	56, 57	Load Transport, Passenger Transport
Other Transport	55, 58-60	Railways, Sea Transp., Air Transp., Other transport.
Services	61-73	Communications, Banks, Insurance, Rents, Serv. to firms, House Prop., Public and Private Education, Public and Private Health, Entertainment, Other Entertainment, Other Services , Public Adm.

ANNEX C: Comparison of Impacts With and without Capital Mobility

The following table shows the differences in impacts in choosing full capital mobility against zero capital mobility across sectors. The results show that when full capital mobility is allowed the impacts on output of the sectors are much higher. This is due to the possibility to install and uninstall capital, which allows the sectors to adjust their production at a lower cost. This will however have a negative impact on households, since the winning sectors will no longer require high amount of additional labor, and hence the average wage will decrease slightly.

From a macro perspective impacts are slightly higher on GDP, consumption and investment, while they are relatively smaller on production, and trade. This latter is due to the possibility to switch capital from one sector to another, increasing output in winning sectors. Finally, from an environmental view, the impacts are also slightly higher, which is due to the growth of cleaner energy sector.

Variable		No capital Mobility	Full Capital Mobility
Macroeconmic	Production	-1.00%	-0.80%
	Consumption	-1.00%	-1.20%
	Investment	0.50%	0.80%
	Exports	-1.60%	-1.50%
	Imports	-1.50%	-1.20%
	Real GDP	-0.50%	-0.60%
	Absorption	-0.50%	-0.50%
	Real Gov. Savings	11.40%	14.20%
	Corporate Savings	-0.90%	-1.10%
Sectoral Production	Renewables	-1.00%	-1.80%
	Non Renewables	-0.80%	3.30%
	Oil and Gas Extraction	-11.50%	-14.50%
	Coal	2.10%	11.10%
	Food	-0.60%	-0.80%
	Textiles	0.00%	0.70%
	Wood	-0.90%	-2.10%
	Chemicals	-0.50%	0.00%
	Oil Refinery	-26.80%	-32.60%

	Machinery	-0.10%	1.10%
	Electricity	0.60%	10.10%
	Gas	-1.20%	0.30%
	Hydraulic	-0.10%	0.70%
	Construction	0.40%	0.70%
	Commerce	-0.50%	-0.50%
	Load and Passenger Transport	-3.60%	-5.30%
	Other Transport	-3.50%	-13.60%
	Services	-0.10%	0.40%
Real Income	Quintile I	-1.00%	-1.30%
	Quintile II	-1.00%	-1.30%
	Quintile III	-1.00%	-1.30%
	Quintile IV	-1.00%	-1.20%
	Quintile V	-0.90%	-1.10%
Environment	SO2	-17.30%	-19.90%
	NO2	-17.00%	-19.60%
	CO	-5.90%	-3.80%
	VOC	-2.90%	-3.00%
	PM10	-15.80%	-17.90%