ENVIRONMENTAL TAXES, INEFFICIENT SUBSIDIES AND INCOME DISTRIBUTION IN CHILE: A CGE FRAMEWORK

Raúl O´Ryan*
Sebastian Miller y Carlos J. de Miguel**

Abstract

Successful economic growth followed by Chile, based on open market and export strategy, is characterised by a high dependence on natural resources, and by polluting production and consumption patterns. There is an increasing concern about the need to make potentially significant trade-offs between economic growth and environmental improvements. Additionally, policy-makers have been reluctant to impose standards that could have regressive consequences, making the poor poorer. Using the ECOGEM-Chile model we study the direct and indirect effects of imposing green taxes in Chile for PM10, SO2 and NOx as well as taxes on gasoline. We analyse the effects over macroeconomic variables as well as sectoral, distributive and environmental variables. We also analyse eliminating distotionary subsidies that produce environmental and welfare losses. Evidence of welfare gains, besides environmental gains, and trade-off among sectors is presented that can justify tax/subsidies reforms in developing countries, replacing inefficient taxes/subsidies for more efficient ones.

Keywords: Environmental Taxes, Double Dividend, Computable General Equilibrium (CGE), Energy Subsidies.

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* Centro for Applied Economics and Program for Environmental Economics and Management, Industrial Engineering Department, Universidad de Chile.
** Sustainable Development Area, Center for Public Policy Analysis, Universidad de Chile

I.- Introduction and history

The debate on the need to balance economic growth and environmental impact appeared on the scene in 1972 when the Club of Rome issued its “Limits to Growth” publication. Although this study had fundamental shortcomings because it did not take economic forces into account, it did generate much awareness on ecological matters. Ever since, the debate has continued with more and less controversial stands, but integrating environmental and economic variables more appropriately (The Economist, 1997; Dasgupta and Mäler, 1998; Kneese, 1998). In 1987, the Brundtland Commission defined the term “sustainable development” as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In practice, this definition considers that any developing society must achieve its economic, environmental, and social goals simultaneously (Pearce and Turner, 1990). Socio-economic goals consider the need for economic growth, increased justice, and improved efficiency. Environmental goals include system integrity, biodiversity, the ability to assimilate, and global concerns. Finally, social objectives include participation, social mobility, cultural identity and institutional development, among other concerns.

The Chilean Environmental Framework Law incorporates the concept of Sustainable Development by supporting the idea that there can be no strong and stable progress unless social justice and environmental care exist at the same time, which increase the possibilities of fostering economic growth while protecting the environment, eliminating poverty and attaining more social equity.

Chile’s successful growth of the past decade is well known, and so is the comparative strength at the regional level that the country showed to cope with the Asian crisis. Social policies have been significant, and have resulted in a remarkable improvement in the Chilean people’s health care and education. Also noteworthy are the 38% and 60% reduction in the number of extremely poor and poor, respectively, in less than ten years. However, 23.2% of the population is still below the poverty line, and the unequal distribution of income (wealth) remains with no visible change (MIDEPLAN 1997, 1998).

But this economic and social situation has left its print on the country’s natural and environmental capital. Economic growth has been largely based on primary product exports, directly related to the exploitation of natural resources. In 1995, agriculture, forestry, fishing and mining accounted for a combined 15% of Chile’s current GDP, and for 47% of total exports. Another 26% is accounted for by primary-product-low-transformation sectors such as the food, wood and paper industries.

On the other hand, comparing the relative growth and export evolution of the aforesaid sectors in real terms, it appears that generally –and particularly the agricultural and fruit sectors– have experienced relative reductions in their price evolution, which are believed to be causing a negative effect on the country’s terms of trade.

In addition, economic growth has caused the creation of substantial pollution that affect the country’s environmental quality. The development of manufacturing and mining industries, not always with environmentally "friendly" technologies, together with the concentration of the population in cities with no serious land planning to support the migration, and the rapidly increasing number of privately owned vehicles, among other factors, have taken their toll on the quality of water, air, and soil, and thus on the people's quality of life.[1]

With the creation of the National Environmental Commission CONAMA, the Chilean Administration took a step forward in unifying the environmental policies, through an agency that would identify the most critical aspects, create policies and monitor the enforcement of regulations, standards and other measures applicable. There is a clear need to create mechanisms that would permit evaluating the concept of sustainability in a measurable way, systematically analyzing its three macro-objectives (i.e. economic growth, social equity and environmental sustainability), also proposing alternative actions in various scenarios for any of them. In general, however, studies are made within a partial equilibrium context, which makes it difficult to analyze the implications of environmental protection measures on equity and efficiency.

The complexity of direct and indirect relationships between economic, environmental and social variables calls for models that allow evaluating priorities and policies consistent with sustainability. Computable general equilibrium models are multiple sector models that try to represent a country's economy realistically, and have proven to be useful instruments to describe these relationships together with providing an ex-ante quantitative evaluation of the effects of different policies.

Initially, these models were applied to examine poverty and income distribution problems, although later, trade issues took precedence among the applications. Today, environmental issues (not forgetting social equity-related problems) have moved up the priority scale, following the international diffusion of the concept of sustainable development[2].

The application of CGE models is important in a number of environmental aspects:

a) Models used to assess the effects of trade policies or international trade agreements on the environment (Lucas et al 1992, Grossman and Krueger 1993, Beghin et al. 1996, Madrid-Aris 1998, or various applications within the framework of the Global Trade Analysis Program, GTAP).
b) Models used to assess Climate Change or Global Warming (Bergman 1991, Jorgenson and Wilcoxen 1993, Li and Rose 1995, or Rose et al 1998), usually focusing on the stabilization of CO2, NOx and SOx emissions.

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1 The Index of Sustained Economic Welfare, albeit criticizable, (Neumayer, 1999), was run for Chile (Castañeda 1997), and showed that over the past 30 years, despite the accumulated growth of 88% in production, welfare has decreased by an estimated 4.9%, which shows the trend divergence since the financial crisis of 1982.

2 Gunning and Keyzer (1993) perform a review of computable general equilibrium model applications to developing countries.

c) Models focusing on energy problems (Piggot et al. 1992, Goulder 1993, Rose et al. 1995). These tend to use energy taxes or pricing to assess the potential impact of energy price changes on pollution or cost control.
d) Natural resource allocation or management models (Robinson and Gelhar 1995, Mukherjee 1996). Their objective is the efficient inter-regional or inter-sector allocation of multiple-use natural resources, such as water resources in agriculture, mining, manufacturing, tourism, human consumption, and ecological watercourses, to mention a few.
e) Models focusing on evaluating the economic impact of specific environmental regulations such as the US Clean Air Act or of environmental instruments (Jorgenson and Wilcoxen 1990, Hazilla and Kopp 1990).

In this article, the Computable General Equilibrium Model ECOGEM-Chile will be applied in order to analyze the direct and indirect effects of imposing new taxes on fuel, PM10, SOx and NOx emissions on the level of emissions, production by sectors, and income distribution.

After a brief introduction to the Chilean environmental reality, the theory on environment-related taxes and the concept of double dividend, Section III will describe the CGE model and the data used. Section IV presents different environmental tax scenarios and possibilities of governmental compensation to remain in the initial real public savings (expenditure) situation. The objective is to analyze tax reforms that may reduce the emission of different pollutants, together with improving income distribution. The impact of eliminating subsidies to coal production is also analyzed. Section V concludes.

II.- Environmental Status and Taxes

Only in the last decade, have concerns regarding the health and environmental costs of Chile's economic expansion been voiced strongly. Nevertheless, policies and programs for sustainable development still play a secondary role in Chile. The historical lack of environmental regulations and laws, or their ineffective application, has resulted in the accumulation of many environmental problems, of which the most important are:

(a) Air pollution, linked to urban areas, industrial activities (pulp and paper, fishmeal), mining and electricity generation. In specific areas, emissions of different pollutants exceed the national normative or the international recommendations.
(b) High levels of water pollution caused by domestic and industrial effluents without treatment. It affects surface water, ground water and coastal seawater.
(c) Water scarcity at regional level
(d) Inadequate urban development management, high levels of pollution, green or recreational areas scarcity, etc.
(e) Inappropriate solid waste management and disposal, in particular hazardous wastes.
(f) Land erosion and degradation, associated to poor agricultural and forestry techniques, urban growth and inadequate solid waste management. It mainly affects agricultural land and river basins.

(g) Threats to native forest due to overexploitation (increase of forestry activity, coal making, wood collection) and absence of effective protection.
(h) Hydro-biological resources overexploitation and biomass exhaustion
(i) Poor management of hazardous chemical substances.

The tradeoff between a better environment and growth, required to solve the important social problems discussed in the previous sections, is very clear in the case of Chile. Many of the most important economic sectors are related to natural resources (mining, forestry, agriculture, and fishery), thus any action that reduces activity in these sectors may have regional and/or countrywide impacts. Investments in pollution reduction, in particular in Santiago, will require significant layouts, not necessarily paid exclusively by those affected.

Air pollution in Santiago is the most obvious environmental problem of the country, however other cities are also being affected. For Santiago, natural variables, demographic growth, fix sources and mobile sources are principal causes. However, important reductions in PM10 and PM2,5 (23,3 % and 46 % respectively) have been achieved since 1989. The decontamination plan, elimination of 3.000 highly polluting buses, the incorporation of natural gas in the productive process of fixed sources, and introduction of catalytic converters in all new vehicles (as a result 50% of cars in Santiago 1999 have converters) are main determinants of this improvement. Nevertheless, in 1999 there were 14 environmental pre-emergency events, the maximum of the 90s, and one emergency event was declared[3].

Table Nº1 Santiago Environmental Situations in the 90´s

Year	Pre-emergency	Emergency	Year	Pre-emergency	Emergency
1990	11	2	**1995**	2	0
1991	9	2	**1996**	6	0
1992	14	2	**1997**	13	0
1993	8	0	**1998**	12	1
1994	3	0	**1999**	14	1

Source: SESMA (1999)

Index	**CO** ppm	**SO2** μg/m^3	**NO2** μg/m^3	**O3** μg/m^3	**Particulate** μg/m^3
301-400	30	1.493	2.110	780	240
501 - >	50	2.620	3.750	1.400	330

[3] An Emergency Program is being applied since 1990. It establishes several levels of air quality. When pollution overcomes the 300-air quality index pre-emergency is declared, and emergency for 500 index. The level is associated to:

Transport is the largest sector in terms of air pollution. Mobile sources account for 92.3% of carbon monoxide, 70.6% of nitrogen oxides, and 45.7% of Volatile Organic Compounds derived from fuel use. Private transport is generally more polluting in terms of concentration of pollutants per vehicle mile traveled than public transport, except for PM10 emissions (see Table, p9, CONAMA, Libro Resumen del Medio Ambiente)

The following table shows Santiago's air quality compared to other major cities that are highly contaminated. It can be concluded that air quality is a major problem in the city.

Table Nº2 City Comparison of Air Pollution

City (population in 1000's)	Total suspended particles	Sulfur dioxide	Nitrogen dioxide
Calcutta (11,923)	375	49	34
Beijing (11,299)	377	90	122
Mexico City (16,562)	279	74	130
Tehran (6,836)	248	209	..
Bombay (15,138)	240	33	39
Bangkok (6,547)	223	11	23
Santiago (4,891)[4]	**210**	**29**	**81**
Manila (9,286)	200	33	..
Athens (3,093)	178	34	64
Sao Paolo (16,533)	86	43	83
Lisbon (1,863)	61	8	52
Ankara (2,826)	57	55	46
Tokyo (26,959)	49	18	68
WHO Recommendations	**60-90**	**40-60**	**..**

Because of differences in location and measurement, city comparisons are only indicative.
Commercial city center, μg/m^3 annual averages, 1995
Source: World Bank databases (SIMA)

Table Nº3 Air Pollution in Santiago (1995)

Pollutant	**CO[b]**	**Ozone[c]**	**PM10[a]**	**PM2,5 [a]**	**SO_2 [a]**	**NO_2 [a]**	**TSP [a]**
Max.	35.6	224	302	174	161	254	621
Min.	0.1	1	8	4	7	4	31
Average[5]	2.04	13	87	42	17.8	64.8	186.3

[a] data in μg/m3, [b] in ppm, [c] in ppb.
Source: SESMA, INE

Other problem areas in Chile include poor air quality in Concepción-Talcahuano from steel, petroleum, fishmeal, paper and pulp industries and high levels of ground level

[4] Average is not relevant in Santiago concerning the wide range of variation among the highest and lowest concentrations.
[5] The annual average is calculated as the annual average per month of all monitoring stations.

Ozone in Valparaiso-Viña del Mar. In this sense, Talcahuano environmental recovery plan is operating and air monitoring systems are been establishing in several cities with the goal of identify saturated zones. The following table summarizes air quality problems by region.

Table Nº4 Air Quality Problems by Region

Pollutant	Source	Affected Area
PM10	Copper Smelting Petroleum Refinery Cement Production Diesel Motors	II, III, V, VI Regions V Region V Region SMA
SO2	Copper Smelting Petroleum Refinery Cement Production	II, III, VI Regions V Region V Region
Ozone	Copper Smelting Petroleum Refinery Cement Production Vehicles	V Region V Region V Region SMA
Sulfhydric Acid	Pulp and Paper Fishmeal Industry	VII, VIII and IX Regions VIII Region
Trimethylamine	Fishmeal Industry	VIII Region
CO and CO2	Vehicles	SMA
NOx	Vehicles	SMA

Source: CONAMA-Univ de Talca-Univ. de Concepción

The biggest threat to health from air pollution comes from fine particles. Studies indicate that there are significant effects on human health. For this reason, several territories have been declared "saturated areas" for specific pollutants:

Table Nº5 Saturated Areas in Chile

Region	Territory	Saturated of:	Year
II	Maria Elena, Pedro de Valdivia Areas	PM 10	1993
II	Chuquicamata Camp	SO2, PM 10	1991
II	Potrerillos Smelter Area	SO2, PM 10	1997
III	Hernán Videla Smelter Area	SO2	1993
V	Chagres Village	Latent SO2	1991
V	Ventanas Smelter Area	S02, PM10	1993
VI	Caletones Area	S02, PM10	1994
RM	Santiago Metropolitan Area	PM10, CO2, O3, latent Nox	1996

Source: CONAMA

Finally, other problems related to air are acoustic pollution in the city of Santiago and bad smells surrounding fish meal and pulp and paper industries as well as dumping grounds.

Despite these efforts, it is still necessary to continue reducing emissions, at an increasing private cost. Therefore, alternative scenarios must be analyzed in order to achieve larger reductions of –in this case– PM10, SO2 and NO2.

The meta-objective should be to attain optimal pollution levels, that is, to set a socially optimal level of activity where the marginal net private benefit equals the marginal cost generated by externalities. Because of the many theoretical and practical difficulties of determining such a level of activity and create the proper measures to attain it, normally the attempt is made to reach “acceptable” pollution levels. Some times the authorities substitute more easily applicable emission limits for Pigouvian[6] taxes or pollution fees, both because public institutions are more used to them and because they are more politically acceptable.

In reaction to this regulatory practice that favors command and control instruments, a vast literature that seeks to promote the use of economic instruments has developed. These are more efficient, particularly because they allow achieving goals cost-effectively and, at the same time, encourage technological innovation. Reviews on direct economic regulatory instruments for pollution control and their applications on the international scene can be found in Pearce and Turner (1990), Repetto et al (1992), OECD (1994), Sterner (1994b), O´Ryan and Ulloa (1996), among others.

Among the most frequently applied “green” tax options for air pollution control, the following stand out:

i) Taxes on emissions or effluents (a charge on the quantity and/or quality of air pollutants) are applied in China, Poland, France, Sweden, etc.

[6] The Optimal Pigouvian Tax is the equivalent of the damage caused by one marginal pollution unit in the pollution optimum.

ii) Charges to activities causing an environmental damage (charges to the user of contaminating processes or administrative charges on operations) are applied in Singapore, Denmark, Sweden, etc.

iii) Charges to products (differentiated taxes that put a heavier burden on polluting products) are used in the Netherlands, Sweden, Norway, etc.

There are experiences on the application of these instruments, especially in Europe, but also in development countries, such as China. In practice, taxes have been used more to collect money than to encourage a reduction in pollution.

Recently, the international literature has focused on analyzing the "double dividend" concept"[7]. This concept highlights the potential gains from replacing the existing tax structure that taxes "goods" by one whereby externalities are taxed. Thus, by introducing an environmental tax that will replace other distorting tax (in terms of economic efficiency, income distribution, etc.), and keeping fiscal collection constant, the quality of the environment would be improved in addition to reducing economic distortions and improving welfare. This concept has been thoroughly examined in developed countries, where studies have been extended into the search for joint improvements in employment, output, income distribution, environmental quality, and other indicators. However, the results of the studies are inconclusive as to whether or not double dividend exists.

In any case, introducing environmental taxes may be beneficial even because of only the first dividend, that is, improving the environment's quality and correcting the associated externality. Therefore, studies on the use of economic instruments for environmental management (and eventually the existence of double dividend) maintains its interest and can undoubtedly shed some light on future policies and their expected effects.

In the case of new taxes substituting for existing ones in the pursuit of joint economic, environmental and/or social improvements, Fullerton and Metcalf (1997) conclude that each type of reform must be evaluated separately. Therefore, one can not believe in advance in the existence of double dividend *per se*. Moreover, because every country has different tax structures and labor markets, to extrapolate a successful reform from one country to another will not necessarily have the same results. Parry and Oates (1998) consider that the results of the studies must not rule out the use of economic instruments, but rather encourage new studies since there can be no certainty on the results of any future environmental tax reform. In addition, they warn about the inability of partial equilibrium studies to consider indirect effects of tax reforms on the different sectors..

This work will look for evidence of double dividend in the sense of concurrent improvements in income distribution and air quality. The first objective of the applied environmental taxes will be to reduce air pollutant emissions. From this necessary condition, a tax structure change will be looked for that will permit to improve equity while keeping real public saving constant. In this case, the double dividend will be "ethical" since there is no reason why the replaced taxes in the fiscal reform will be less disturbing from an

[7] In-depth discussions on the issue of "double dividend" can be found in Repetto et al (1992), Goulder (1994), Fullerton and Metcalf (1997), Bosello et al (1998), Bento (1998), Jaeger (1999).

economic efficiency standpoint. In any case, the evolution of economic activity with respect to the initial situation –before the policy– will also be controlled.

III.- The General Equilibrium Model: ECOGEM-Chile

III.1.- Characteristics of the model

The CGE developed for Chile is a static model characterized by sector multiplicity, occupational category differentiation, income quintiles, trade partners, and specified productive factors, among other features.[8] It is basically a neoclassic model, which is savings-driven. It incorporates energy-input substitution to reduce emissions because the emissions are related to the use of different inputs and not only to production levels as is generally dealt with.

Although not all the model's equations are shown herein, the most significant will be included, 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

<u>Production</u>: 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:

$$\min \; PKEL_i KEL_i + PABND_i ABND_i$$
$$\text{s.t.}$$
$$XP_i = \left[a_{kel,i} KEL_i^{\rho_i^p} + a_{abnd,i} ABND_i^{\rho_i^p} \right]^{1/\rho_i^p}$$

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 factors` side, the capital-energy basket and labor is split through a new CES function, and then energy is

8 The model presented herein, ECOGEM-Chile, has been developed by PDS/CAPP 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).

separated from capital, always assuming CES functions for substitution both between and within factors (types of labor, energy, and capital)[9].

Income distribution: Production-generated income is allocated in the form of wages, capital returns and taxes between the domestic economy, the Government, and the domestic and international financial institutions.

Consumption: households distribute their income between saving and consumption through an ELES utility function (Extended Linear Expenditure System)[10]. This function also incorporates the minimum subsistence consumption as independent from the level of income.

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

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

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

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.

Other Final demands: Once the intermediate demands and household demands are defined, there is only to include the rest of the final demands, i.e. investment, government spending and trade margins. Other final demands of each item are defined as a fixed share of total final demand.

Public Finances: regarding public finances, there are different types of taxes and transfers. The following are defined in the model: labor tax (differentiated by occupational category), taxes on firms, on income (differentiated by quintile), all of them direct. Also import tariffs and subsidies are defined, together with export taxes and subsidies, (by sector) and a value added tax VAT (for domestic and imported goods, and by sector).

As a closure condition for public finances, the model allows two alternatives: first, government spending is defined as fixed and equal to the original level previous to any simulation, allowing it to adjust through some tax or government transfer. Second, government spending is allowed to vary, while taxes and transfers are kept fixed. The first option was chosen herein.

9 See Annex #1, to see the way the nest is built.

10 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.

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:

$$\min \; PDXD + PMXM$$

$$\text{subject to} \quad XA = \left[a_d XD^{\rho} + a_m XM^{\rho}\right]^{1/\rho}$$

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 or the "Armington good". Parameter ρ is the substitution elasticity between both goods.

For exports:

$$\max \; PD\, XD + PE\, ES$$

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

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.

Factor Market Equilibrium Conditions: 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; for this case no capital mobility between sectors is assumed.

It is worth noting that long-term elasticities have been assumed for the substitution between the factor nest and non-energy-producing inputs, as well as for the CES between capital-energy and labor, between capital and energy, and for the various energy-producing sectors. Although this assumption allows for greater substitution between factors is more realistic from a medium term viewpoint.

Closure Conditions: the closure condition for the public sector has already been anticipated. 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 the Walras Law.

III.2.- Emission Reduction Within 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. Number two is associated to the use of energy-producing inputs that discharge emissions into the environment whenever they are used in the productive process or in consumption, and allows to substitute less contaminating elements for the more so. Number three is determined by the ability to reduce emissions by the way of "end of pipe" technologies (e.g. filters, treatment plants, and the like). 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 supposedly less polluting technologies, because it would be necessary to use a dynamic model. Although it is actually 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.

<u>Production Reduction</u>: 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).

<u>Substitution between inputs</u>: 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 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:

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

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[11] in the productive processes of all the sectors, in their consumption by households "*h*" and by other components of the final demand "*f*".

<u>"End of Pipe" technologies:</u> 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[12]. 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:

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

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

11 Not only energy-producing.
12 Abatement technology is the current expenditure in technology to comply with some green regulation or to avoid paying some environmental tax.

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

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:

$$E_p = \sum_i \upsilon^{*p}_i \cdot XP_i + \sum_j \sum_i \pi^{*p}_i \cdot X_{ij} + \sum_i \pi^p_i \left(\sum_h XAc_{ih} + \sum_f XAFD^i_f \right)$$

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.

III.3.- The data

<u>III.3.a.- Economic Data</u>

As in any general equilibrium model applied, the main source of information is the Chilean social accounting matrix. The matrix available was built on the basis of information from the Chilean Central Bank (Venegas, 1995) and Alonso and Roland-Holst

(1995) with the input-output matrix for the year 1986. This matrix has been updated up to 1992, and a new matrix is expected that will cover up to 1996.

The social accounting matrix for Chile that is used preliminarily was reduced in order to enable a better mathematical convergence, without diminishing its capacity to analyze relevant political scenarios. It has 18 economic sectors[13], the labor factor divided into skilled and unskilled, it includes the foreign sector, disaggregates household income into five quintiles, and incorporates the new abatement sector (in the matrix presented herein this sector has only been formally disaggregated until definite processed data are available). The matrix is measured in billions of pesos of 1992 purchasing power, although in this type of exercise, measure units and amounts are not so relevant as are the variables' ratio accuracy (relative weight).

As for the income, substitution, and other elasticities used, because this is a static model, it is possible to chose long-term elasticities used in the relevant international literature, thus providing more flexibility to the adjustment process and more realistic results. However, investment and capital accumulation processes as a function of relative returns may not be incorporated, and long-term elasticities only minimize this flaw.

III.3.b.- Data Bases to Calculate Emissions

Energy-producing Inputs: For the Chilean case, the input-output matrix sectors considers 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.
- Water (Hydraulic): hydraulic and sanitary operations sector.

Because the SAM's updating to 1992 is based on the input-output matrix of 1986, the gas sector is undervalued. In this sense, any sector GDP increases or reductions will be smaller than would be expected in reality. With the coal sector, the opposite occurs. Section IV.4 presents a simulation that attempts to duplicate the current situation of this latter sector and the economy.

Emission coefficients: there are two types of emission coefficients. One comes from inputs used and the other is related to the productive processes. On the other hand, there are 5 types of pollutants identified, namely: SO2, NO2, VOC (volatile organic compounds), CO and PM10.

[13] The specific sectors are described in Annex 2.

The emission coefficients of each of the aforesaid pollutants, associated to the use of inputs, are obtained from regressions whose endogenous variable is the pollutant and the exogenous variables are the 15 sectors chosen as the main generators of pollutant emissions in the United States. Observations are associated to all the sectors of activities of the SAM in that country which use each of the 15 inputs. The minimum limit for degrees of freedom is 70 (85 sectors using at least one of the 15 inputs minus 15 types of input-exogenous variables). No constants are used and the maximum number of activity sectors is 345. Once the coefficients associated to the use of inputs have been calculated, fictitious variables are included for those sectors that are the cause of emissions of some pollutant independently of the type of input used. Thus the emission factors associated to production are obtained, independently of the inputs used. To extrapolate the data to Chile the national SAM figures were used, thereby obtaining the levels of emissions on the bases of the valued amount of the inputs used[14].

IV.- The policies

To formalize a policy option in the model, various alternatives exist of which three are worth singling out:

(a) To set –exogenously– a tax associated to the emission of one unit of a specified pollutant in order to attain some specified reduction in the overall economy's level of emissions:

$$\tau_{Poll} = P \cdot \tau_{Poll}$$

(b) To determine a maximum level of emissions for one or every pollutant. In this case the tax is not determined exogenously but as the shadow price that results from including this new environmental constraint in the optimization function.

(c) Taxing (subsidizing) the use of one or more polluting inputs.

IV.1.-Taxes on PM10, SO2, NO2 Emissions

The immediate objective of this study is to determine the impact on the level of SO2, NO2, CO, VOC, PM10 emissions that may result from applying environmental taxes to emissions of a specified pollutant. To do this analysis three scenarios were simulated where a 10% reduction in the emissions of the respective pollutant was set, namely PM10, NO2, and finally SO2.

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

In all the scenarios the environmental tax is offset by reducing another tax in such a way that real public saving does not vary from its initial situation. Corporate taxes and VAT are the offsetting taxes used in all three.

In this sense, the compared analysis to the results shows that taxing PM10 emissions to reduce them by 10% brings about larger reductions in the rest of the pollutants than if emissions of NO2 or SO2 are taxed. This results persists independently of the offsetting tax.

The only exception is emissions of CO. In this case, a tax on emissions of SO2 that is offset by an earnings tax triples the reduction in CO emissions induced indirectly (see Figure 1 and Table 6). The reason is the relative fall in the coal sector's production associated to its lower relative absorption. In the other scenarios, the coal sector's absorption was also reduced, although in this case its relative reduction is much larger. This, because of the larger emissions of SO2 compared to the rest of the energy-producing inputs, and not being comparatively so affected by the earnings tax cut. Section IV.4 analyses in more detail the coal sector with specific simulations that show impacts by sector (and especially those associated specifically to the coal sector) derived in this work.

Table Nº6: Reduction of 10% of PM10 Emissions

			Compensatory Tax			
			Corporate Tax		VAT	
Policy Impacts	Macro	Real GDP	0.0	%	0.0	%
		Investment	0.2	%	-0.3	%
		Consumption	-0.4	%	-0.2	%
		Exports	-1.5	%	-1.5	%
		Imports	-1.5	%	-1.6	%
	Sectoral	Water	1.3	%	3.3	%
		Electricity	0.7	%	1.4	%
		Gas	0.5	%	2.3	%
		Other Transports	-3.4	%	-3.4	%
		PetroGas	-4.5	%	-4.5	%
		PetroRef	-11.2	%	-11.2	%
	Distributive	RealYD-IQuintil	-0.8	%	0.2	%
		RealYD-IIQuintil	-0.6	%	0.2	%
		RealYD-IIIQuintil	-0.4	%	0.1	%
		RealYD-IVQuintil	-0.4	%	-0.1	%
		RealYD-VQuintil	-0.3	%	-0.5	%
	Environmental	Emissions SO2	-11.0	%	-11.1	%
		Emissions NO2	-11.0	%	-11.0	%
		Emissions CO	-3.2	%	-3.0	%
		Emissions VOC	-2.3	%	-1.7	%
		Emissions PM10	-10.0	%	-10.0	%

Once the environmental impacts of emissions are analyzed, the study will focus on macro-sectoral consequences. As for macroeconomic variables, non of the applied policies has a material or significant effect. The marginally negative (non-significant) sign of impacts on total output, consumption, imports and exports, is linked to slights declines in the model's price indexes, because the Real GDP is not affected. In any case, the costs of adjustment will depend on how gradually will these policies be implemented. This must be linked to the possibilities of substituting between production factors and/or between energy-producing inputs, to the capital's degree of mobility between sectors, and to the technological changes affecting both the productive processes and consumption patterns.

Regarding the sectors, there are many similarities between winner and loser sectors for the various scenarios. In general, the most penalized sectors are those directly linked to the production of petroleum-derived fuels, or those sectors that require them as inputs. The case of coal whenever SO2 emissions are taxed is again the exception, since it reduces emissions by up to 14.3%.

Table Nº7: Reduction of 10% of NO2 Emissions

			Compensatory Tax			
			Corporate Tax		VAT	
Policy Impacts	Macro	Real GDP	0.0	%	0.0	%
		Investment	0.2	%	-0.2	%
		Consumption	-0.4	%	-0.2	%
		Exports	-1.4	%	-1.4	%
		Imports	-1.4	%	-1.5	%
	Sectoral	Water	1.2	%	3.0	%
		Electricity	0.6	%	1.2	%
		Gas	0.5	%	2.1	%
		Other Transports	-3.1	%	-3.1	%
		PetroGas	-4.1	%	-4.1	%
		PetroRef	-10.2	%	-10.2	%
	Distributive	RealYD-IQuintil	-0.8	%	0.2	%
		RealYD-IIQuintil	-0.5	%	0.2	%
		RealYD-IIIQuintil	-0.4	%	0.1	%
		RealYD-IVQuintil	-0.3	%	-0.1	%
		RealYD-VQuintil	-0.3	%	-0.4	%
	Environmental	Emissions SO2	-10.1	%	-10.1	%
		Emissions NO2	-10.0	%	-10.0	%
		Emissions CO	-3.0	%	-2.8	%
		Emissions VOC	-2.1	%	-1.6	%
		Emissions PM10	-9.1	%	-9.1	%

With any of the policies applied, transport has been the most affected non-energy-producing sector. The Other Transport sector (tables 6 through 8), which includes – basically air, sea, and railroad transport, has been more affected than freight transport or highway use by passengers, but differences are not substantial. The negative impact on the highway transport sector's output fluctuates between a drop of 2.3% (PM10 emission tax offset by a corporate tax) and an increase of 2.0% (SO2 emission tax offset by VAT).

The remaining sectors are not affected significantly, although there are differences in signs depending in the offsetting tax imposed (Figure 3). For example, the construction and service sectors are negatively affected by VAT increases, and positively if they are offset with corporate taxes. The opposite is true for the food and textile industries.

As for income distribution, the results systematically infer that to offset environmental taxes with earnings taxes is less re-distributive than doing so with VAT (tables 6 through 8 and Figure 4).

Table Nº8: Reduction of 10% of SO2 Emissions

			Compensatory Tax			
			Corporate Tax		VAT	
Policy Impacts	Macro	Real GDP	0.0	%	0.0	%
		Investment	0.1	%	-0.2	%
		Consumption	-0.3	%	-0.2	%
		Exports	-1.4	%	-1.4	%
		Imports	-1.4	%	-1.4	%
	Sectoral	Water	1.4	%	3.0	%
		Electricity	0.3	%	1.2	%
		Gas	0.8	%	2.1	%
		Other Transports	-3.2	%	-3.1	%
		PetroGas	-3.4	%	-4.1	%
		PetroRef	-9.7	%	-10.1	%
	Distributive	RealYD-IQuintil	-0.8	%	0.2	%
		RealYD-IIQuintil	-0.5	%	0.2	%
		RealYD-IIIQuintil	-0.4	%	0.1	%
		RealYD-IVQuintil	-0.3	%	-0.1	%
		RealYD-VQuintil	-0.2	%	-0.4	%
	Environmental	Emissions SO2	-10.0	%	-10.0	%
		Emissions NO2	-10.0	%	-9.9	%
		Emissions CO	-9.0	%	-2.7	%
		Emissions VOC	-2.0	%	-1.6	%
		Emissions PM10	-9.8	%	-9.1	%

In the former case, and for all the pollutants taxed, the real income of all the quintiles decrease, although more so in the lower-income quintiles. This is associated to a larger relative decline in unskilled labor wages. While offsetting with VAT reductions results in 60% of the lower-income population improving their income, the income of the next 20% will decline by around one third less than with an corporate tax cut, and finally the wealthiest 20% of the population would reduce their real disposable income by no more 0,05%.

In terms of welfare, equivalent and compensatory variations were calculated for each quintile, with similar results to those of income.

Anyway, and because variations are never as large as 1%, that is, not very significant, we agree with the thesis of Engel, Galetovic and Raddatz (1998) whereby the Chilean tax structure has little direct effect on income distribution.

IV.2.- Fuel Taxes

The fourth policy applied was a fuel tax. The objective was to raise this tax until a 10% reduction in PM10 emissions has been achieved. To this end, a 150% increase in the tax rate on fuels was necessary.

Similarly, real public saving was kept at the reference level and the same offsetting scenarios were proposed, i.e. an corporate tax cut and a reduction in the VAT.

Table Nº9: Increase the Fuel Tax in 150%

			Compensatory Tax			
			Corporate Tax		VAT	
Policy Impacts	Macro	Real GDP	0.0	%	0.0	%
		Investment	0.5	%	0.2	%
		Consumption	-0.9	%	-0.8	%
		Exports	-2.1	%	-2.0	%
		Imports	-2.1	%	-2.1	%
	Sectoral	Water	1.1	%	2.1	%
		Electricity	0.7	%	1.0	%
		Gas	1.4	%	2.4	%
		Other Transports	-3.1	%	-3.0	%
		PetroGas	-7.5	%	-7.4	%
		PetroRef	-20.9	%	-20.5	%
	Distributive	RealYD-IQuintil	-1.1	%	-0.5	%
		RealYD-IIQuintil	-0.9	%	-0.4	%
		RealYD-IIIQuintil	-0.8	%	-0.5	%
		RealYD-IVQuintil	-0.9	%	-0.7	%
		RealYD-VQuintil	-0.9	%	-1.0	%
	Environmental	Emissions SO2	-11.2	%	-10.9	%
		Emissions NO2	-11.0	%	-10.7	%
		Emissions CO	-3.2	%	-3.0	%
		Emissions VOC	-4.0	%	-3.6	%
		Emissions PM10	-9.9	%	-9.6	%

The results obtained were very similar to those in the scenario where PM10 emissions are taxed. Although in both offsetting scenarios VOC emissions are reduced by almost twice as much as when taxing PM10, and offsetting by increases in corporate taxes appears better in terms if relative emissions.

Macroeconomic impacts are slightly more restrictive, although at the sector level disparities arise (Table 6 versus Table 9). Obviously, sectors related with fuel production, transformation, and sale suffer this tax more intensely and their sectoral output is reduced by roughly twice as much as if the tax is imposed on PM10 emissions. The gas sector appears as the "winner".

Offsetting by VAT appears slightly better in terms of macro-sectoral impacts.

In terms of distribution, taxing fuels has a larger negative impact on all the income quintiles, although offsetting with VAT is relatively better. On the other hand, taxing fuels reveals as a more regressive tax because it causes larger reductions in the lowest-income quintile (the relative weight of fuels in their consumer basket is higher).

In general, taking a closer look at the economic, distributive and environmental impacts together, taxing fuels appears to be less desirable than taxing PM10 emissions.

IV.3.- The Tax System

The closure rule assumed for all the simulations performed consists in keeping government savings constant. To that end, either VAT or corporate tax cuts has offset any environmental tax.

Table Nº10: Changes in Tax Rates when Emissions are Reduced

Tax	Reducing	Δ Tax Rate (%)
PM10 Emissions	Corporate	-30.8
	VAT	-18.8
NO2 Emissions	Corporate	-28.1
	VAT	-17.2
SO2 Emissions	Corporate	-32.9
	VAT	-17.1
Fuel	Corporate	-18.2
	VAT	-10.6

In this sense, offsetting VAT reductions range from 10% to 19% of the current tax rate in force in terms of actual collection (Table 10), whereas corporate tax reductions vary between 18% and 33%[15].

[15] Note that the model considers actual revenue; therefore, tax rates existing in Chile for VAT or corporate taxes will not necessarily match the respective payments by sector.

IV.4 The Coal Sector

One limiting factor associated to CGE models is the number and quality of the data used, especially the Social Accounting Matrix. In this sense, after examining the one used herein, the conclusion is that the coal sector was overestimated in relation to the current Chilean conditions. This, because of the presence of subsidies that do not exist today that made it "profitable" for producers and consumers of this energy-producing input. As of today, coal production has decreased dramatically, from 1,667,341 tons in 1994 to 378,654 in 1998 (Central Bank, 1999). For this reason, a simulation was made with the CGE model of the elimination of every subsidy to coal, and reassigned the resources to transfers to households, in such a way as to keep public saving constant (a realistic scenario because the redundant workers of the sector are being "helped" by the Government).

This simulation attempted to duplicate what occurs today in that sector as well as in those related in some way with it[16]. From a macroeconomic perspective, there are no changes in the aggregate variables of the economy. Real GDP, Absorption, Consumption, Investment, Exports, Imports, etc. are not altered. From the standpoint of income distribution, this scenario is believed to be positive because the first (poorest) quintile's income increases by 0.7% where as in the fifth (wealthiest) it decreases by barely 0.1%. The remaining quintiles are believed to increase their real income by less. This because of the 1.7% increase in transfers to households associated to the substitution of the coal sector's subsidy.

Total emissions in the economy of the various pollutants are not altered materially, with the exception of carbon monoxide that decreases by 7.8%, followed by PM10 with a reduction of only 0.8 %. Since there is no impact in macroeconomic terms, and from the environmental and distributive viewpoints impacts are slightly positive, this policy appears correct and shows a modest evidence of double dividend.

At the sector level impacts are greatest, valued coal production falls by 43.2% associated with a 61% loss in the rate of return and the impossibility of shifting the subsidy reduction to a price increase (these may only rise by 8% because of the domestic coal (-17.3 %) being replaced by imported (+6.3%) and this input's absorption being reduced 4.6%). In any case, the drop in production is even larger if measured in physical units than in money value. The other sectors show no material impact, because the possible effects of a coal price increase are offset by the greater resources released and the demand for the rest of the economy.

These results enhance understanding of the previous ones, because in the earlier scenarios the coal sector was subsidized. Therefore by taxing emissions, this sector would keep some premium returns over other energy-producing sectors (i.e. gas, oil, electricity) as a result of the aforesaid subsidies. Therefore, substituting towards gas or electricity, other inputs, capital between sectors, etc. was not all that optimal. In any case this fact, being an

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[16] Long-term substitution elasticities and no capital mobility between sectors were assumed as in the rest of the scenarios analyzed in the paper.

inefficiency of the market's allocation system, is only undervaluing the positive results presented.

Another important result of this analysis is that when it is compared to reality, we observe very similar results. In the end we can validate the model with these results.

V.- Conclusion

This article analyzes the impact of different tax reforms tending to improve the environment, comparing their effects on aggregate output, output by sector and income distribution. To this end, within the ECOGEM-Chile model's framework, four possible environmental taxes were tested, with each of them offset in terms of collection in such a way that public savings (expenditure) remained equal to the original situation.

The environmental taxes were applied on emissions of PM10, SO2, NO2 and on fuels. Offsetting taxes chosen to keep public saving constant were earnings taxes and VAT.

The direct objectives were to reduce the emissions of the taxed pollutants by 10%, and for gasoline, to achieve a near 10% reduction in PM10.

Among the most outstanding findings were:

a) Taxing PM10 emissions leads to larger reductions in the emissions of the other pollutants (SO2, NO2, CO, VOC) than doing so on emissions of SO2 or NO2. This result held true independently of the offsetting tax, with the exception of CO.

b) The most severely penalized sectors are those directly related to the production of oil-derived fuels or transportation. The most favored are those related with the production of alternative energy-producing inputs.

c) Income distribution is not affected significantly by the chosen tax scheme. Still, it can be inferred that offsetting the environmental tax with a cut on corporate taxes is less progressive than with the VAT. However, from a strictly environmental perspective, to offset with a VAT reduction is associated with smaller reduction in pollutant emissions.

d) In general, taking a closer look at the economic, environmental and distributive impacts, the fuel tax appears to be less advantageous than a tax on PM10 emissions. Moreover, although the one that reduces VOC emissions the most appears to be the most regressive tax, affecting most adversely the poorest quintile of income.

e) The final simulation has two important consequences. In the first place it demonstrates that eliminating coal subsidies is an efficient policy, and despite what has been said, it does not affect the poor negatively. On the other hand, this simulation enhances the model`s results, in the sense that it can replicate actual policies with a quite good degree of precision.

Ultimately, as a policy objective and from an environmental standpoint, taxing PM10 emissions appears to be the best choice. If also distribution improvements are sought for, this tax will have to be offset with a reduction in the VAT although, in any case, the Chilean tax structure does not seem to affect income distribution materially. Therefore, no clear-cut evidence exists of double dividend in any of the alternatives examined, although deeper research on this point seems necessary.

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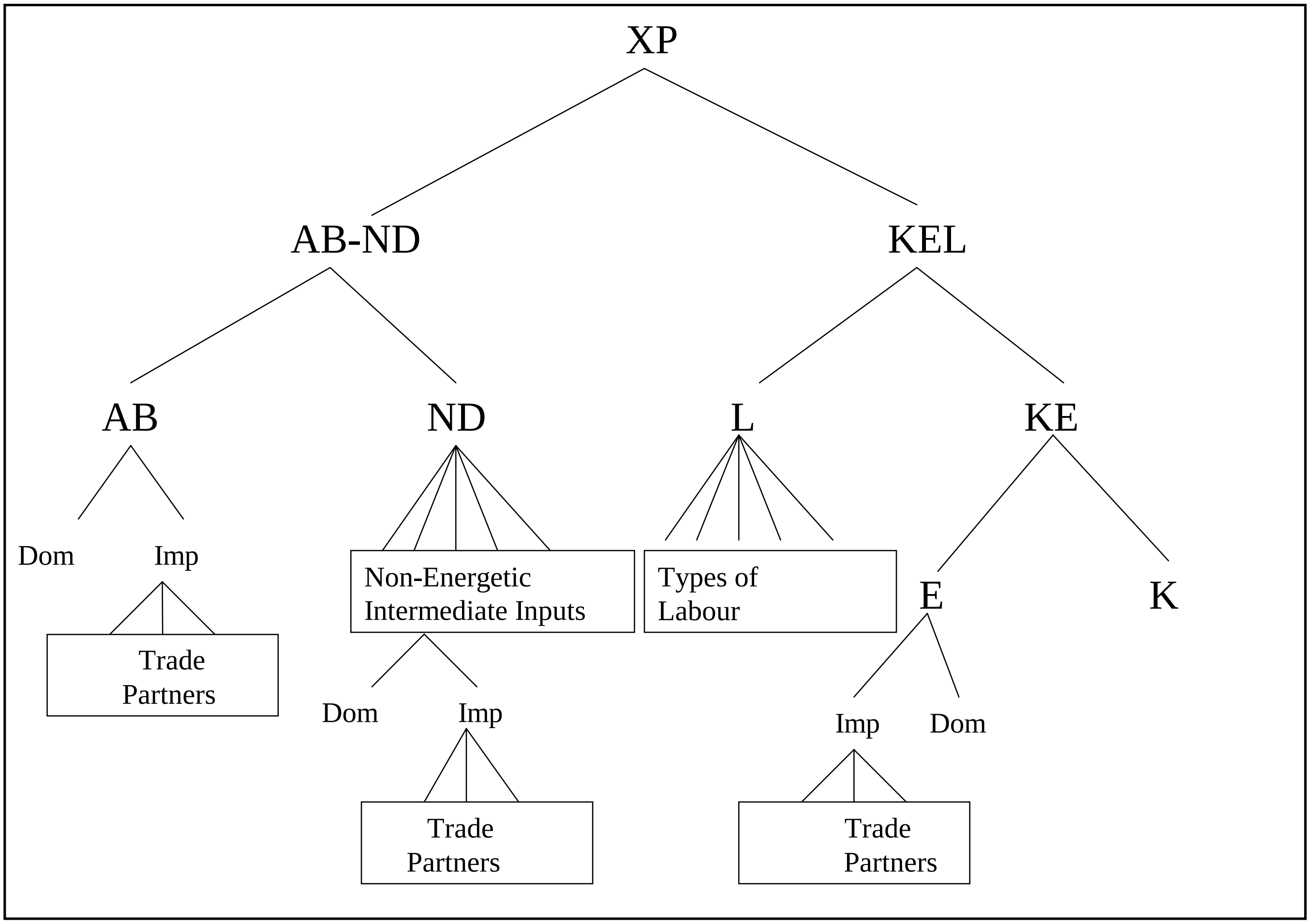
ANNEX 1: Production Nesting



ANNEX 2: Sectors Used

Sectors	Reference to 1986 SAM	Description
Renov	1-6	Agriculture, Fruit, Livestock, Agriculture Serv., Forestry, Fisheries
NoRenov	7,8,11	Copper, Iron, Other Minerals
PetrGas	9	Extraction of Oil and Gas
Coal	10	Coal
IndAlim	12-23	Slaughter, Diary, Conserves, Sea Food, Oils, Bakery, Sugar, Other Foods, Feedstock, Drinks, Wine and Liquor, Tobacco
IndTex	24-27	Textile, Clothes, Leather, Shoes
IndMad	28-30	Wood Products, Furniture, Pulp and Paper
IndQuim	31-33, 35-38	Printing, Chemicals, Other Chemicals, Rubber, Plastics, Pottery, Glass
PetrRef	34	Refinery
IndMaq	39-46	Non metalic minerals, Basic Metals, Metalmechanics, Non Electric Machinery, Electric machinery, Transport Materials, Professional equipment, other manufactures
Electrcty	47	Electricity
Gas	48	Gas
Hydraulic	49	Hydraulic
Construct	50	Construction
Commerce	51-53	Commerce, Restaurants, Hotels
TransRod	55, 56	Load Transport, Passenger Transport
TransAlt	54, 57-59	Railways, Sea Transp., Air Transp., Other transport.
Services	60-74	Comunications, Banks, Insurance, Rents, Serv. to firms, House Prop., Public and Private Education, Public and Private Health, Entertainment, Other Entertainment, Repair, Other Services , Public Adm.

ANNEX 3: Figures

Figure 1: Reduction of Total Emissions when Taxing Emissions of PM10, NO2, SO2 Reducing Corporate Taxes

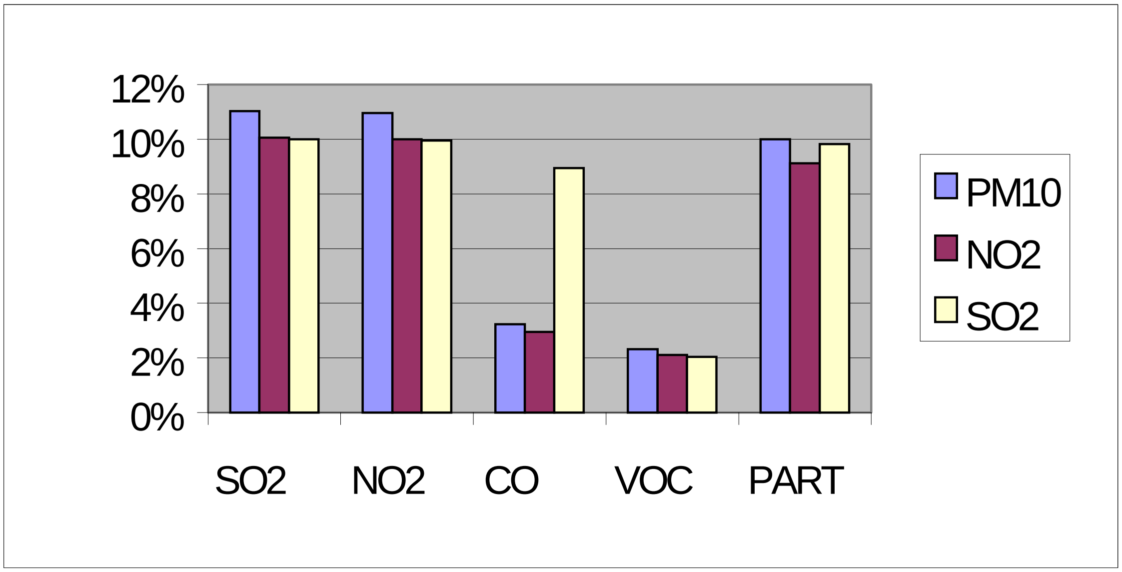


Figure 2: Reduction of Total Emissions when Taxing Emissions of PM10, NO2, SO2 Reducing VAT

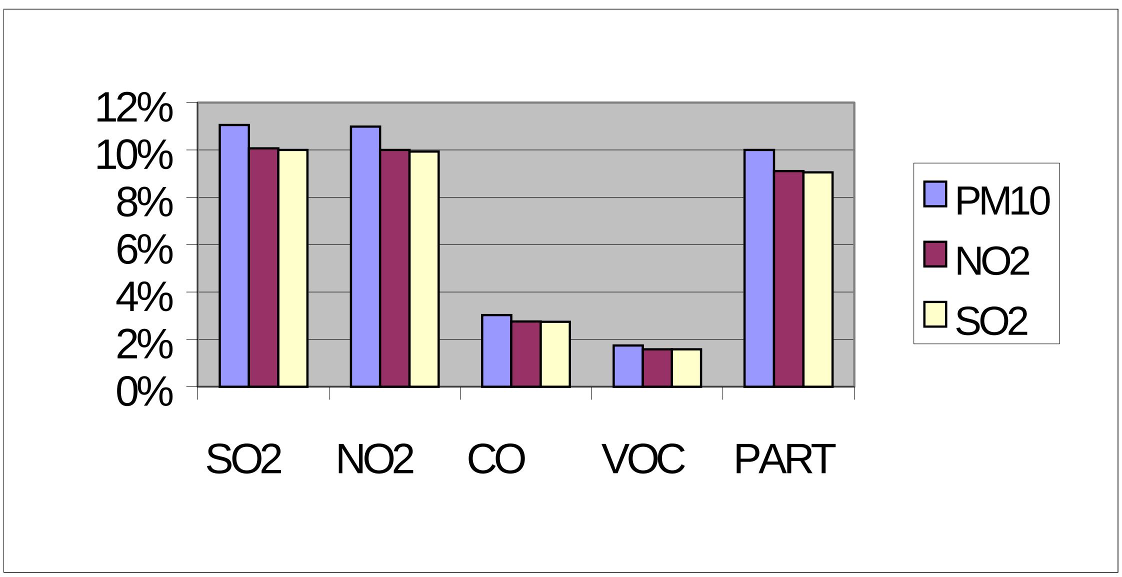


Figure 3: Sectoral Impact of Taxing Emissions of PM10, compensating with a Reduction of VAT and Corporate Taxes.

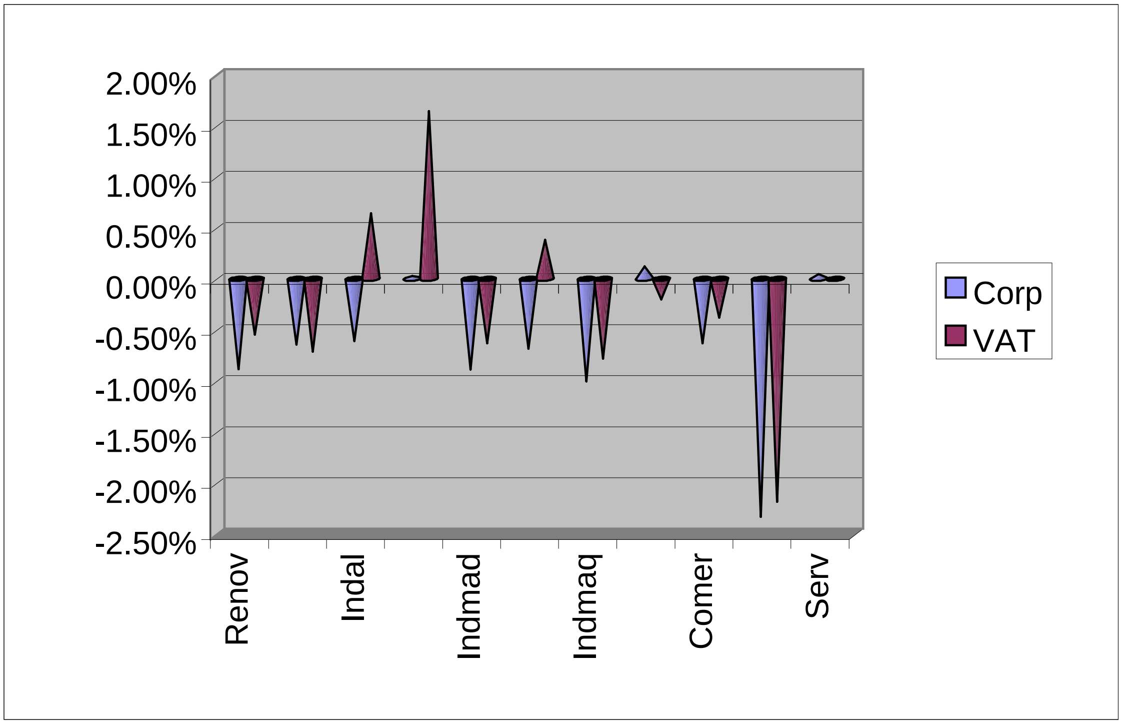


Figure 4: Distributive Impact of Taxing PM10, SO2 and NOx Emissions Reducing VAT and Corporate Taxes.