ANALYSIS

Computable general equilibrium model analysis of economywide cross effects of social and environmental policies in Chile

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Abstract

The analysis of the linkages between development policies and social and environmental variables is a neglected area within the development literature. This paper focuses on the key interrelations among the economic, social and environmental elements of the sustainable development triangle. A thorough review is undertaken of both social and environmental policies in Chile, underlining important economic growth and reforms. Using the static CGE model ECOGEM-Chile, the economywide impacts of several environmental, social and combined policies are simulated for the Chilean economy. Six different policies are simulated—three environmental policies that impose different taxes on PM10, SO_2 and NO_2 emissions, respectively; the same tax on PM10 in a context of high unemployment; one social policy that increases government transfers to households; and a mixed social-environmental policy package where the environmental tax on PM10 and the social transfer policy are simulated simultaneously. The results show that environmental tax policies may have negative social effects, using real disposable income by quintiles as proxy. The impacts depend on the use of the new revenues and the status of employment. Taxing PM10 emission yields better environmental results than taxing SO_2 and NO_2. Social policies do not show negative environmental impacts. Combined environmental and social policies improve results. Thus, specific compensating social policies would improve environmental policy acceptance, while also reducing poverty or strong income distribution disparities. The evidence suggests that environmental policies may have social impacts, but not vice versa. The results show that the ECOGEM-Chile model is useful for analyzing systematically and holistically, different economywide policies and their impact on the Chilean economy. Winners and losers may be identified, as well as the potential magnitude of gains and losses. The results obtained are not all straightforward, due to indirect effects.

Keywords: PM10; Social transfer policy; ECOGEM-Chile model

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1. Introduction

In the 21st century, the concept of sustainable development is receiving increasing attention from world decision makers, in their search for new solutions to many critical problems including traditional development issues (such as economic stagnation, persistent poverty, hunger, malnutrition and illness), as well as newer challenges (like, worsening environmental degradation and accelerating globalisation). Governments have taken the responsibility to promote sustainable development—in response to Agenda 21 adopted unanimously at the 1992 United Nations Conference on Environment and Development (*UNCED*) in Rio 1992 and followed up at the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg.

While no universally acceptable practical definition of sustainable development exists, the concept has evolved to encompass three major points of view—economic, social and environmental (Munasinghe, 1992). For our purposes, sustainable development may be defined as a process for improving the range of opportunities that will enable individual human beings and communities to meet their needs, as well as to achieve their aspirations and full potential, over a sustained period of time, while maintaining the resilience of economic, social and environmental systems (Munasinghe, 1994). This wider perspective on human well-being has encouraged researchers to look beyond traditional development goals like maximizing economic output, and pay more attention to environmental and social effects.

In this paper, we analyze the interrelation among environmental and social policies and their cross effects as well as the impacts on the key macroeconomic and sectoral variables, within a general equilibrium macroeconomic modeling framework applied to Chile. Thus, our work is the natural extension of a major trend in the literature, which has sought to examine countrywide or economywide policies (both macroeconomic and sectoral) and their powerful and pervasive impacts on environmental and social issues (see, for example, Munasinghe and Cruz, 1994; Reed, 1996; Munasinghe, 2002).

In the remainder of this section, we summarize the computable general equilibrium (CGE) modelling framework that is used, and then review the relevant literature. Section 2 describes the main economic, social and environmental issues and policies in Chile. The ECOGEM-Chile model is applied to explore alternative environmental and social policies, and simulation results are discussed in Section 3. Finally, Section 4 summarizes the main conclusions.

1.1. Computable general equilibrium (CGE) approach

A general equilibrium approach will capture complex inter-linkages among economic, environmental and social variables, better than partial equilibrium methods. It is often difficult to integrate these three major domains (and associated systems). The economic domain is geared mainly towards improving human welfare, primarily through increases in the consumption of goods and services. The environmental domain focuses on protection of the integrity and resilience of environmental systems. The social domain emphasizes the enrichment of human relationships and achievement of individual and group aspirations, including equity.

Since the precise definition of sustainable development remains an elusive (and perhaps unreachable) goal, it is more promising to pursue a less ambitious strategy that merely seeks to 'make development more sustainable' (Munasinghe, 1994). Thus, our study focuses on beneficial (or adverse) changes in selected economic, environmental and social variables. Such an incremental (or gradient-based) method is more practical, because they help to identify and eliminate many unsustainable activities—often avoiding sudden catastrophic ('cliff edge') outcomes. The practical goal is an approach that will (inter alia) permit continuing improvements in the present quality of life at a lower intensity of resource use and reduced environmental degradation, thereby leaving behind for future generations an undiminished stock of productive assets (i.e., manufactured, natural and social capital) that will enhance opportunities for improving their quality of life.

Macroeconomic policies and strategies have widespread effects—typically, they range from exchange rate, interest rate and wage policies, to trade liberalization, privatization and similar programs. They are usually coupled with various sectoral measures, including pricing in key sectors like energy or agriculture, as well as broad sectorwide taxation or subsidy programs. Such economywide policies are often packaged within programs of structural adjustment, stabilization and sectoral reform, aimed at promoting economic stability, efficiency and growth, and ultimately improving human welfare. Even though their primary objectives might be economic, countrywide policies have pervasive (and sometimes unforeseen) environmental and social consequences.

Thus, the complexity of the direct and indirect interrelations among economic, environmental and social variables calls for models that capture these complex linkages, and allow us to generate policy options that make development more sustainable. At the same time, these models must take into account market mechanisms and behavior of economic agents, which determine the effectiveness of public policies and achievement of desirable structural changes in the economy.

In this context, computable general equilibrium (CGE) models represent the economy of a country in a more realistic way by incorporating market mechanisms in the allocation of resources. Also, they have proved to be useful in defining the main relationships in the economy, and in evaluating quantitatively *ex-ante* the effects of different economic, social or environmental policies, while capturing indirect side effects which in many cases are not evident on an intuitive basis.

Fig. 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 and consumers. Additionally,

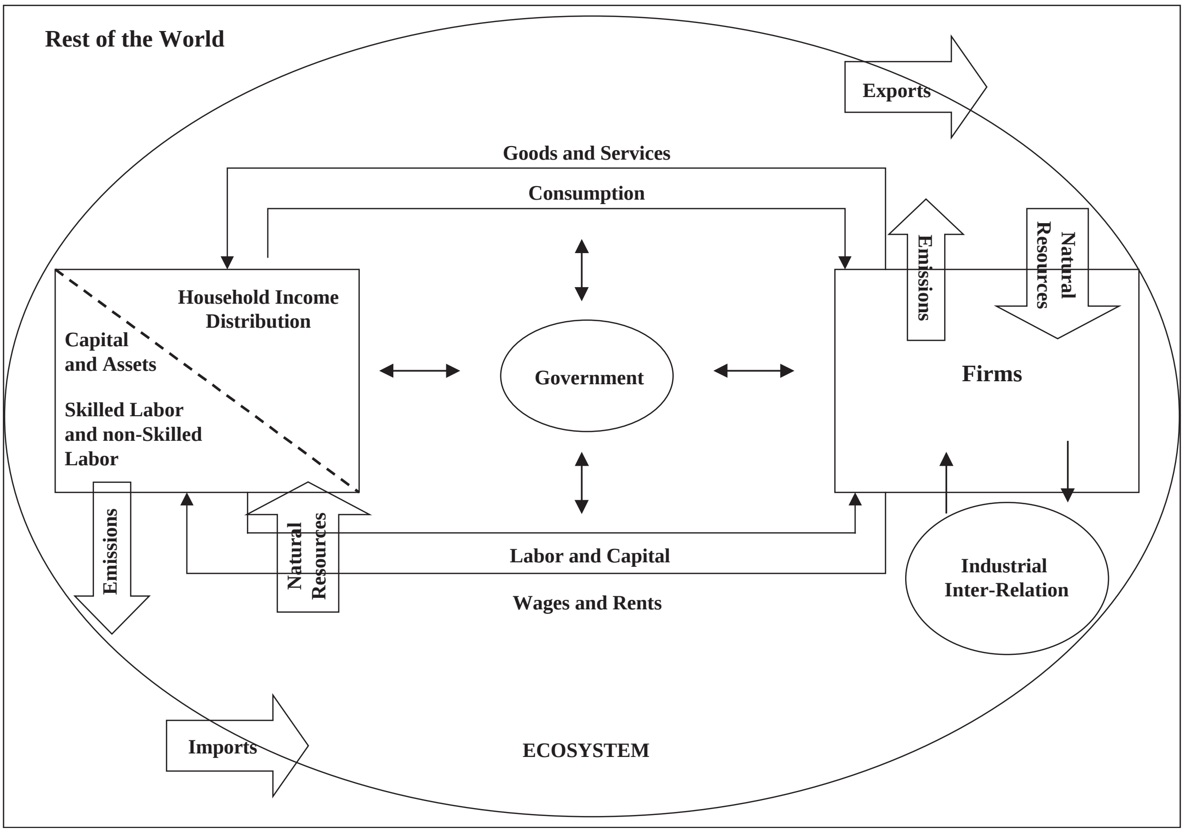

Fig. 1. Economy circular flow.

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 reach equilibria according to Walras law, that is to say, by equating demand and supply at all markets, thus determining prices and quantities. A fundamental characteristic of the productive sector in these models is that, in the same way as input–output models, they incorporate the demands for intermediate inputs and not just capital and labor. However, they differ from the input–output models by allowing substitution among production inputs. This characteristic furnishes equilibria, which take into account the transmission of the effects through all the relevant markets. Additionally, the government role is modeled applying taxes, subsidies and transfers.

Finally, it must be noted that the CGE model has integrated the analysis of long-term perspectives into the generation of development strategies and growth paths, with the short-term perspective focused on contingent situations and stabilization policies. All this without loosing sight of the relevance of sectoral aspects related to technological or investment processes.

1.2. Relevant applications of CGE models

1.2.1. Worldwide applications

CGE models have become a standard method for analyzing a wide variety of traditional economic policies: structural adjustment, trade, taxation, foreign exchange, etc. (see the survey by Gunning and Keyser, 1993). More recently, other elements of sustainable development, including social, environmental, poverty and equity issues have been investigated, using general equilibrium methods (Conrad, 1999; Munasinghe et al., 2005).

After the initial use of a CGE model in Norway (Johansen, 1960), the first set of applications focused on problems of optimal taxation and trade policies in developed countries. Almost two decades later, applications to developing countries emerged (Adelman and Robinson, 1978 for Korea and Taylor et al., 1980 for Brazil). Throughout the 1980s, applications in developing countries evolved from the issues of poverty, income distribution and development strategies, through structural adjustment and stabilization policies to solve the debt crisis, trade problems and strategies. In the nineties, CGE models were used to analyze poverty and income distribution issues, as well as environmental problems (Devarajan, 1997; Adkins and Garbaccio, 1999).

Models for developing countries have become more practical and realistic, by moving away from the strict neoclassical framework of the original general equilibrium approach. Typical adaptations include departures from the Walrasian orthodoxy to account for structural rigidities like fixed wages, absence of mobility factor (Taylor, 1990), as well as permitting imperfect competition and increasing returns to scale in trade models.

1.2.2. Linkages with the environment

Empirical research carried out at the World Bank in the late 1980s and early 1990s, including the application of CGE models to environmental issues, highlighted several conclusions that are relevant for this paper (Munasinghe and Cruz, 1994). One main outcome of this work was that it is difficult to generalize about the environmental and social impacts of economywide policies, since linkages tend to be extremely complex and country specific. Nevertheless, some general conclusions do emerge.

On the positive side, liberalizing reforms such as the removal of resource price distortions, promotion of market incentives, and relaxation of trade and other constraints, often contribute to both economic and sustainability gains (i.e., win–win outcomes). For example, policies that improve the efficiency of industrial, or energy related activities, could reduce economic waste, increase the efficiency of natural resource use and limit environmental pollution. Similarly, improving land tenure rights and access to financial and social services not only yields economic gains but also promotes environmentally sustainable land management and helps the poor.

In the same vein, evidence indicates that short-run policy measures aimed at restoring macroeconomic stability will generally yield economic, social and environmental benefits, since instability undermines sustainable resource use and especially penalizes the poor. For example, price, wage and employment stability encourage a longer-term view on the part of firms and households alike. Lower inflation rates not only lead to clearer pricing signals and better investment decisions by economic agents, but also protect fixed income earners.

On the other hand, economywide structural reforms have had adverse environmental and social side effects. Such negative impacts are invariably unintended and occur when some broad policy changes are undertaken while other hidden or neglected policy, market or institutional imperfections persist. The remedy does not generally require reversal of the original reforms, but rather the implementation of additional complementary measures (both economic and non-economic) that remove such policy, market and institutional difficulties. These complementary measures are not only socially and environmentally beneficial in their own right, but also help to broaden the effectiveness of economywide reforms (see below).

Typical examples of potential environmental damage caused by *policy distortions* include export promotion measures that increase the profitability of natural resource exports and encourage excessive extraction or harvesting of this resource if it were underpriced or subsidized (for example, low stumpage fees for timber). Similarly, trade liberalization could lead to the expansion of wasteful energy-intensive activities in a country where subsidized energy prices persist.

Meanwhile, *market failures* such as external environmental effects of economic expansion (such as air or water pollution) induced by successful adjustment, may cause excessive environmental damage, if these externalities are not adequately reflected in market prices that influence such activities.

Finally, unaddressed *institutional constraints*, like the poor accountability of state-owned enterprises (which would allow them to ignore efficient price signals), weak financial intermediation or inadequately defined property rights, tend to undermine incentives for sustainable resource management and worsen equity.

The shorter-term stabilization process may also have unforeseen adverse environmental and social impacts. For example, general reductions in government spending are often required to limit budgetary deficits and bring inflation under control. Unless such cutbacks are carefully targeted, they may disproportionately penalize expenditures on environmental protection or poverty safety nets (Barcena et al., 2002). Another important linkage is the possible short-term necessary impact of adjustment on poverty and unemployment, whereby the poor are forced to increase their pressures on fragile lands and "open access" natural resources—due to the lack of economic opportunities elsewhere. In this case, appropriate measures designed to address the possible adverse consequences of adjustment will be justified—on both social and environmental grounds.

Finally, economywide policies will have additional longer-term effects on sustainability, whose net impacts are less predictable. Some of these effects need to be traced through a general equilibrium framework that captures both direct and indirect links. For example, adjustment-induced changes often succeed in generating new economic opportunities and sources of livelihood, thereby alleviating poverty and helping to break the vicious cycle of environmental degradation and poverty. Higher incomes tend to increase the willingness-to-pay for better environmental quality, which leads to greater protection of the environment. However, while such growth is an essential element of sustainable development, it will increase the overall pressures on environmental resources. At the same time, properly valuing resources, increasing efficiency and reducing waste will help to reshape the structure of economic growth and limit undesirable environmental impacts. Finally, environmental policies themselves could have impacts on income distribution and employment.

Many of these conclusions are illustrated by the use of CGE models applied to developing countries, in recent publications by Persson and Munasinghe (1995), Dessus and Bussolo (1996), Munasinghe (1996), Rodríguez et al. (1997) and De Miguel and Miller (1998).

More generally, since the first environmental CGE models appeared (Forsund and Storm, 1988; Dufournaud et al., 1988), the recent literature includes applications in many major areas, such as (a) models used to evaluate 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; Yang, 2001; Beghin et al., 2002) or diverse applications in the area of the Global Trade Analysis Program (Hertel, 1997); (b) models used to evaluate climate change, which are usually focused on the stabilization of CO_2, NO_x and SO_x emissions (Bergman, 1991; Jorgenson and Wilcoxen, 1993; Li and Rose, 1995, or Rose and Abler, 1998; Edwards et al., 2001); (c) models focused on energy issues, which usually apply energy taxation or pricing to evaluate the impacts that changes in the price of energy can have on pollution or costs control (Pigott et al., 1992; Rose et al., 1995); (d) natural resource allocation or management models, whose objective is usually the efficient interregional or inter-sectoral allocation of multi-use natural resources—for example, allocation of water resources among agriculture, mining, industry, tourism, human consumption and ecological watersheds (Robinson and Gelhar, 1995; Mukherjee, 1996; Ianchovichina et al., 2001); and (e) models focused on evaluating the economic impacts of environmental instruments, or of specific environmental regulations, such as the Clean Air Bill in the USA (Jorgenson and Wilcoxen, 1990; Hazilla and Koop, 1990).

Finally, double dividend issues have been a recent hot topic where CGE models have been increasingly applied. The theory of optimal taxation in the presence of externalities, i.e., the environmental taxation based on Pigou principles (Auerbach, 1985), has been under continuous discussion both on theoretical grounds and in empirical studies. Repetto et al. (1992) demonstrated in a partial equilibrium framework, how "green" tax reforms can improve the welfare of the economy by recycling the revenue to reduce distorting taxes. The debate on the existence of a double dividend derived in the necessity of applying general equilibrium frameworks. Thus, CGE models have been used to argue in favor or against the existence of a double dividend (Bovemberg and De Mooij, 1994; Bovemberg and Goulder, 1996; Fullerton and Metcalf, 1997; Bento and Rajkumar, 1998; Bosello et al., 1998; Parry and Oates, 1998; Jaeger, 1999; Koskela et al., 1999; Parry and Bento, 1999, etc).

1.2.3. Applications in Chile

The applications of computable general equilibrium models to Chile are few. Early applications tried to analyze the effects of alternative taxation policies on the rest of the economy. For example, Ruiz and Yarur (1990) used a recursive dynamic small and open economy (SOE) model and data from the I/O 1977, to study the effects of different taxation policies on the economy. In general, more recent applications have been dedicated to analyzing the effect of changes in tariff policies, arising from the debate on trade agreements among Chile and MERCOSUR, NAFTA, European Union, United States of America and Asia-Pacific. Coeymans and Larraín (1994) carried out a study of the consequences of Chile joining NAFTA. The model is set up for a SOE, and includes six productive sectors and three regions that trade with each other (Chile, U.S., Rest of the World or ROW). Data used for this study is taken mainly from the I/O table of 1986. The results indicate that an agreement between Chile and the U.S. would generate a new composition of trade with the U.S. and that a series of benefits would follow the agreement. Harrison et al. (1997) built a model that uses the database of the GTAP program (Global Trade Analysis Project).[1] This multi-regional model, with 11 regions and 24 productive sectors, is used to analyze the entry of Chile into MERCOSUR, NAFTA, European Community and the rest of South America (RSA), and the effects of trade re-routing. The results of the study indicate that such free trade agreements are sometimes beneficial to Chile, and sometimes not. Harrison et al. (2002) applied the same model to assess the Chilean approach of sequentially negotiating bilateral free trade agreements, focusing on the importance of market access and lowering tariffs.

The work of Bussolo et al. (1998) attempts to analyze the effects of trade agreements by focusing on the labour market. The model includes 24 productive sectors and 7 occupational categories, based on the updating of the SAM from 1986 to 1992. The article analyzes the effects of a tariff reform in two ways. Firstly, a competitive labor market is assumed. This assumption is later relaxed by introducing certain rigidities (changes in salary negotiation and minimum wages).

[1] Project developed at Purdue University for the analysis of world trade, which has generated a global CGE model incorporating homogeneous SAMs for all the countries/regions.

Holand et al. (2002) applied a CGE to analyze the impacts of agricultural reforms consisting of price band removal and elimination of all tariffs on agricultural and food commodities in Chile. Urban employment, rural–urban migration and welfare effects are addressed.

The CGE model by Beghin et al. (1996) is applied to environmental issues—an application of the TEQUILA model developed by the OECD development center. This study endeavors to analyze the environmental impact of implementing environmental policy, trade liberalization and trade agreements by means of a dynamic computable general equilibrium model. For this purpose, a multi-regional model that includes 26 regions and 72 productive sectors is built, which determines the emissions from estimated productive activity at the national level, and scaled for Santiago. The air concentration of particulates is estimated for Santiago by using a linear dispersion model for air pollutants. Finally, a dose–response function is used to translate this concentration into indexes of mortality and morbidity. The results indicate that particulate matter as well as SO_2 and NO_2 are complementary to economic activity, and that their abatement reduces mortality and morbidity significantly. Nevertheless, the analysis of the eventual entry of Chile into NAFTA appears to be beneficial for the environment, whereas the entry into MERCOSUR or a unilateral drop in tariffs will not. Taxing the above mentioned pollutants leads to increased emissions and concentrations of substitutes which are also toxic, as well as bio-accumulative gases, thereby causing a negative net effect on the indices used for mortality and morbidity. Beghin and Dessus (1999) applied a static version of the same model to assess the issue of double dividend, in the sense of substituting trade distortions for environmental taxes.

O'Ryan et al. (2003) applied an adaptation of the OECD model to evaluate policy options for reducing air pollution in Chile. The model incorporated the recently published input–output matrix for Chile.

These last examples illustrate CGE applications that assess economic and environmental linkages. In Chile, there has not been any attempt to evaluate the interrelation between the social and the environmental spheres of sustainable development. Chapter 3 addresses this issue by examining the cross effects of social and environmental policies for Chile.

2. Economic, social and environmental policies in Chile

Since the mid-eighties and up to the end of the last millennium, Chile was viewed as an example for developing countries due to its rapid economic growth, based on an export-led development strategy. Furthermore, there were significant reductions in poverty during that period. However, the environment has suffered severe stress, while policies were applied and enforced to reduce these pressures only after the mid-nineties. This section discusses the main economic, social and environmental issues and policies.

2.1. Economic issues

During the 1980s, Chile engaged in trade liberalization and extensive privatization programs, promoting exports and free markets as the main engines for growth. This trend continued in the 1990s, albeit less strongly. The Government does not set prices, with the exception of public transport, some public utilities and port charges. Tariffs applied to countries without free trade agreements are basically uniform, and currently stand at 6%. Regulatory policies, though limited, have been improved in areas such as utilities, the banking sector, security markets and pension funds.

The main efforts in this period, however, have been in maintaining macroeconomic stability, improving infrastructure provision and focusing resources to reduce many of Chile's unsolved social problems. Legislation is now in place to privatize ports, water and sewage, and will probably be pushed during the next few years. The main reforms implemented during the decade include privatization of public utilities; promotion of private investment in infrastructure, telecommunications, electricity and air transport; trade liberalization and trade agreement expansion; and reform of the educational system. In the future, a system of licenses will probably replace direct privatization.

The policies applied have been very successful, resulting in Chile's economic performance during the 1990s being the best in the last century. The country grew at an impressive 8% per year between 1989 and 1998. The 1997/1998 Asian Crisis shocked the Chilean economy, resulting in a small recession in

1999. Despite adverse international events (slowdown of the international economy, uncertainty after September 11th terrorist attacks, Argentinean crisis, low commodity prices such as copper, fishmeal and cellulose, and a higher oil price, etc.), the economic growth rate in 2000 was a remarkable 4.5%, but decreased to 3.4% in 2001. It is estimated that in 2004 it will reach 5%. Chilean economic performance far exceeds that of other countries in the region (where growth rates are a poor 0% to 1%). Per capita GDP is around US$4500 at current prices.

Relevant variables (inflation, current account deficit, reserves, etc.) have been kept within acceptable limits. Since the beginning of the 1990s, the Central Bank has posted an inflation target for the year, resulting in a fall in inflation from 27% in 1990 to 2.8% in 2002. Government spending has been wise, permitting fiscal surpluses each year up to 1999. In spite of the country suffering from an international situation that impacts negatively on unemployment rates, fiscal expansion has been moderated and the deficit will be easily balanced in the following years. The current account has been in deficit most of the decade (currently, falling below 1% of GDP), but has been easily financed by substantial foreign capital inflows, since Chile's performance has made the country very attractive for investment. External debt composition has changed from 30% private debt in 1990 to 85% in 2002 and is mainly medium and long-term debt (83%).[2] Nowadays, external debt (US$38.989 millions) accounts for 57.6% of the GDP.

Gross internal investment has increased significantly in the period, reaching 27% of GDP in 1998, a very significant increment compared to the 16% average of the 1980s. However, internal savings have not grown much in the decade, and most of the increase in investment has been financed through foreign savings. After 1998, investment slowed down to 23% of the GDP, with a parallel reduction in foreign savings.

As a result of this performance, real wages increased during the 1990s at an average rate of 3.2%. Unemployment fell from an average of 18% in the 1980s to 6% in the 1990s. However, since 1999 unemployment increased to 10% and, despite government's efforts, still remains at 9%.

Poverty has continued to decline, falling from 45% of total households in 1987 to 22% in 1998 and 20.6% in 2000. Although noteworthy regional differences remain, this is a very significant national reduction over such a short period of time. Income distribution is Chile's weak spot. The minimum wage, although increasing at a higher real rate than wages, was only US$160 per month in 2002 (or just around twice the value defined by the poverty line). The richest 20% of households received more than 15.5 times the income of the poorest 20% in 2000; the Gini coefficient was close to 0.58. This situation has remained unchanged since the 1960s.

Finally it is important to note that, historically, Chile's growth has been based on its natural resources, both renewable and non-renewable. Chile is the world's leading copper and iodine producer and a growing source of gold, lithium and other non-metallic minerals. Copper is the main export product, equivalent to more than 40% of its total exports—which fell from 80% in the 1980s, as a result of a continuous diversification of exports. Agricultural products, fish and fishmeal, forestry products and cellulose are other important export sectors that have grown very rapidly in the last decade. Imports are concentrated in capital goods and fuel/energy.

2.2. Social policies

Since 1990, public expenditure on social issues has increased significantly, in order to reduce the high levels of poverty. Following the basic principle of equal opportunities and an acceptable standard of living for the population, social policy in the last decade in Chile has been geared to improving the programs and coverage of the health, education and housing sectors. In addition, efforts has been made to promote productive development in poor areas.

Three distinct periods can be identified in the evolution of social policies in Chile (Schkolnik and Bonnefoy, 1994; Baytelman et al., 1999). During the first period (1950–1973) termed "Universal Policies", there was a gradual growth in public social expenditure, coverage and number of beneficiaries. Programs were designed to have universal coverage, and were basically aimed at health and nutrition, education,

[2] Up to June 2002.

housing and sanitary infrastructure programs. However, these programs were usually underfinanced, causing severe fiscal deficits due to subsequent pressure on the government for more resources.

The second period (1973–1989),[3] called "Assistance and Subsidies", was undertaken during a period of intense economic and political reform. The provision of services by the public sector was decentralized and the private sector encouraged to produce and operate social services. Universal programs were reduced and expenditure focused on specific objectives. The main goal during this period was to eradicate extreme poverty, provide mother–child care and basic services. Social expenditure was severely reduced in the period. Nevertheless, there were significant improvements in human development indicators such as child mortality, reduction of illiteracy and schooling, among others.

The third period, "Integrating Policies", began in the 1990s[4] and is currently in effect. Spending on social objectives has increased substantially. Social policies are focused on improving the quality of services and implementing specific instruments aimed at developing skills in the low-income population. Social *investment* is preferred over assistance. This view is consistent with the new government's goals of economic growth and macroeconomic stability *together* with equality and poverty reduction, not merely as a consequence of growth.

Reflecting the new governments' concern for reducing poverty and income inequality, social expenditure increased strongly during this decade. Between 1990 and 1998, public social expenditure grew by 88% (66% in per capita terms), an annual growth rate of almost 8.2%. This increase was much higher than the regional average for Latin America (5.5%) for the same period (CEPAL, 1999, 2000). As a result, social expenditure rose from 61% of total expenditure in 1990 to 70% in 2002 (see Table 1). This increase in public expenditure in Chile was higher than the growth of GDP for the same period.

Intense reforms were introduced for the health sector in 1980, changing both the structure and the financing. These reforms fostered the creation of a private health system, parallel to the public health service. Beginning in 1990, new criteria for health policies were defined, which included care for the poorest groups, recovery of the public system and an increase in the quality of attention.

Table 1
Central government social expenditures 1990–2002 (percentages of GDP)

	1990	1992	1994	1996	1998	2000	2002
Social expenditures	12.4	12.5	12.8	12.9	14.0	15.6	16.0
Health	1.9	2.2	2.4	2.3	2.5	2.7	2.9
Housing	0.9	1.0	1.0	1.0	1.0	0.9	0.9
Social security	6.1	5.6	5.5	5.4	5.7	6.4	6.4
Education	2.4	2.6	2.7	3.0	3.5	3.9	4.3
Others[a]	1.1	1.1	1.2	1.2	1.4	1.6	1.6
Total expenditures	20.2	20.3	19.9	19.6	21.3	22.4	22.9
Share social/total	61.4%	61.7%	64.2%	66.0%	65.9%	69.5%	69.9%

Source: National Budget Office, Ministry of Finance.
DIPRES (2003) Series Estadísticas, Estadísticas de las Finanzas Públicas 1987–2002.
[a] Includes monetary subsidies and social investment programs oriented to priority groups.

Public investment and expenditure were increased substantially to achieve these goals, and new legislation to reorganize the coexistence between the public and private systems developed. For example, the average sectoral investment in health during the 1990s increased six fold compared to the 1980s, reaching 87 million dollars per year (MINSAL, 1999). As a result, the notorious infrastructure deficit was significantly reduced, recovering part of the hospital capacity and increasing access to health, especially for the poor.

Despite these improvements, the public system is still weak. There is a need to focus more on vulnerable groups; it is necessary to decrease the wide gap between the expenditure by the beneficiary in the public and private sectors. Finally, discrimination based on risk of disease should be avoided in the private sector, since it shifts the burden of elders (80%) to the public system, which has to assume higher disbursements and lower contributions.

In order to achieve these goals, the government has recently proposed a major reform in the public health plan (the AUGE) to be implemented during 2002,

[3] Applied during the military government.
[4] The change in focus is coincidental with the change to a democratic government in Chile.

which guarantees at least 80% financial coverage for 56 major diseases for the whole population. The plan is estimated to cost the government over US$200 million a year and seeks to finance this reform with: higher taxes on diesel, alcohol and tobacco, efficiency gains, higher diesel car permits fee and the elimination of the maternity subsidy.[5] This plan, however, faces strong political opposition, particularly from the dedicated Physicians Association.

Chile's educational system has also suffered intense changes in the last two decades. Chilean education was mainly public up to 1980. At the beginning of the 1980s, this system[6] experienced intense reform, which led to the decentralization of the administration of publicly funded schools, and was transferred to the Municipalities. The reform also allowed the private sector to play a more active role as a supplier of education, introducing a subsidy per student which covers all operational costs. The main objective of this reform was to promote competition among schools to attract and retain students, which should result in increased efficiency and higher quality of education. This educational policy created an increase in access to both elementary and high school education. However, this increase did not improve the quality of the education, and important differences between private and subsidized schools became increasingly apparent. Moreover, public expenditure in education was reduced during the 1980s, from 3.5% to 2.5% of GDP affecting particularly the poorest segments of the population.

In 1990, specific objectives were proposed for this sector, to: (1) improve the quality of education, (2) provide more equal access to education, (3) increase access to education and (4) promote the participation of the different sectors and institutions in educational development. These changes required a notable increase in public expenditure in education, resulting in an increase of 136% between 1990 and 1998 (DIPRES, 2001).

Most expenditure is channeled to elementary education, specifically as subsidies. Elementary education expenditure is almost 6 times higher than pre-elementary expenditure and 2.6 times more than high school expenditure. In addition, in 1995, emphasis was placed on promoting general education of a similar quality for all, reforming high school education to be actualized and diversified, strengthening teacher training, modernizing management of educational systems, increasing investment in education using both public and private funds, and strengthening scientific and technological research. Prominence was given to significantly increasing teacher's salaries.

Between 1990 and 1998, the average educational years for the population over 15 increased from 9 to 9.7 years. In terms of quality, the SIMCE[7] tests of the past years have shown a systematic reduction in the gap between subsidized schools and private schools, as well as the gap between municipal schools and the rest.[8] This public effort must be maintained.

Housing policy has also been a key issue in Chile's current development strategy. The general goal has been to reduce the housing deficit and improve the precarious conditions of the houses belonging to the poor. Housing policy implemented since the late 1970s was focused on the poor, and emphasized a subsidiary role of the state, with private agents playing an active role in the design, localization and financing of the houses. The private sector also defined the standards, costs and quantity of houses. The State's main role was to channel direct and indirect demand for subsidies.

There were basically two housing programs in the early 1990s: construction of social housing and sanitation for houses and neighborhoods. Sanitation consisted of improvements to urbanizing properties and placing property titles in order. The other main program was based on demand subsidies to sectors with a larger savings capability and access to mortgage (MIDEPLAN, 1996). In both cases, houses were built by private construction firms. While in the first program costs were set from the start, the second program could compete in price and quality to attract potential subsided-buyers. As this housing policy was underfinanced, the increasing demand for

[5] In the present, the maternity subsidy is financed by the government and consists in 4 months of wages for all working women. The proposal would use 0.6% of the individual health funds to finance the maternity subsidy.

[6] University education is not considered.

[7] SIstema de Medición de la Calidad de la Educación (system to measure the quality of the education).

[8] For further results, see González (1999).

houses was not satisfied, increasing the housing deficit during the 1980s.

Between 1990 and 1998, public expenditure on housing was around 1% of GDP. Housing policy in the 1990s was aimed at reducing the deficit substantially and improving the instruments used. Beneficiary families were encouraged to participate in the design as well as in the execution and development of solutions. Private sector participation was encouraged, not only as constructors and financiers, but was also extended to incorporate solutions by NGOs and community social organizations.

These policies led to a significant increase in housing solutions in the 1990s compared to the previous decade. The largest budget was channeled through the program of Social Housing, particularly the Basic Housing Program and through the program's subsidies. In terms of focusing of the housing programs,[9] MIDEPLAN (1999b) shows that 53.5% of the benefits given out by the social programs were received by the poorest 40% of the population. The benefits received by the poorest quintile grew from 29.5% in 1996 to 32.1% in 1998.

There have also been important qualitative improvements. According to CASEN (1998), deficit of material (material damage) was reduced by 39%, while deficits in sanitation were reduced by 14% and deficits in houses with both problems decreased by 47%. Despite such efforts, there are still around half a million homes with some kind of qualitative deficit.

Finally, in the 1980s, little attention was placed on improving productivity in poor areas. Promotion of production was focused on modern sectors of the economy, concentrating incentive policies on the exporting sector and bigger companies, which was consistent with the prevailing economic policy of the 1980s. At the end of the 1980s, direct support was given through subsidies for small and medium enterprises to keep them active due to their strong influence on employment. There was little concern for the reduction in productivity levels, and inadequate attention was given to technological innovation, incorporation to the markets and encouragement of modern schemes of production and management (MIDEPLAN, 1996).

This changed during the 1990s as the primary objective of policies in this area were to complement the development of policies undertaken in other areas of the state, with the goal of overcoming poverty. It is expected that through the use and development of their own potentials, persons and communities can improve their living conditions through a gradual and sustained process, while developing a process of social integration. These new criteria in social policies favored the creation of FOSIS (Fund for Solidarity and Social Investment) in 1990, aimed at financing the promotion of productive development in weaker sectors of the economy. Another important concern for funding was that it must support all regions and has to be assigned and used with a high degree of decentralization. According to FOSIS (1997), close to 50% of investment for 1998 was assigned to Regions.

The slower economic growth during 1998–2001 required the government to focus on unemployment issues. The government created about 96,000 new jobs up to May 2002 (MINTRAB, 2002) and subsidized hiring in order to reduce the high unemployment rate. Unemployment subsidy, although approved, is not still applied and amounts involved are small.

Despite the improvements discussed above, the social security safety net in Chile is still weak. The gap between rich and poor is substantial in education, health, housing and other social areas, requiring focused public social transfers to be maintained.

2.3. Environmental issues and policies

Chile has developed an extensive number of environmental regulations and standards up to 1990. These were diverse in nature, dispersed among different sectors, fragmented and without any coordination among them. These regulations were reactions to specific environmental problems at a given time and not part of a coherent policy. As a result, many of the regulations were not applied, due to the uncertainty about their validity, and moreover, a high degree of non-compliance. Nevertheless, environmental protection received strong support in the 1980 Constitution.

[9] Based on CASEN, which stands for characterization of social and economic conditions. It is a national survey, which is held every other year and from which most social indicators are calculated.

Table 2
Environmental expenditures by objective 1999–2001 (thousands of US$)

Objectives according to CEPA[a] 2000		1999	2000	2001[b]
1	Protection of air and clime	6337	13,440	6204
2	Management of liquid waste	12,960	17,428	3833
3	Management and protection of land, underground water and superficial waters	41,087	60,055	48,693
4	Noise pollution abatement	81	347	305
5	Waste's management	45,568	43,754	5352
6	Protection of the biodiversity	41,922	39,654	20,305
7	Other environmental protection activities (including management)	149,332	127,292	70,747
	Total environmental expenditure	297,286	301,970	155,439

Current values at the annual averaged observed dollar (B. Central).
Source: based on Focus (2000).
[a] U.N. Classification of environmental protection activities and expenditure.
[b] Preliminary commitments.

Based on the deteriorated environmental quality, particularly in Santiago, and the need to have an effective environmental policy to defend exports against accusations of ecological dumping, the democratic government, elected in 1990, initiated the restructuring of the sector by setting up the Special Commission for Metropolitan Region Decontamination to improve Santiago's deteriorated environmental quality. A few months later, the National Commission for the Environment (CONAMA) was established. In 1994, the General Environmental Framework Law was passed, reinforcing the previous institutional framework by setting the foundations for the National System for Environmental Management. This institutional development also reinforced environmental expenditures. As a result, the environment related expenditures by CONAMA, Ministries of Economy and Mining and Forestry National Corporation are now 50 times more than in 1990 (Brzovic et al., 2002), having risen to over 2% of the public budget in 2000. The distribution of the expenditures by objectives is presented in Table 2. Environmental authorities regulate and control some activities instead of intervening directly; therefore, environmental expenditures can be transferred to the private sector (for example, in air emissions abatement).

Despite this progress, policies and programs for sustainable development still play a secondary role in Chile, resulting in the accumulation of many environmental problems. The most important include:

(a) Air pollution, linked to urban areas, industrial activities (pulp and paper, fishmeal), mining and

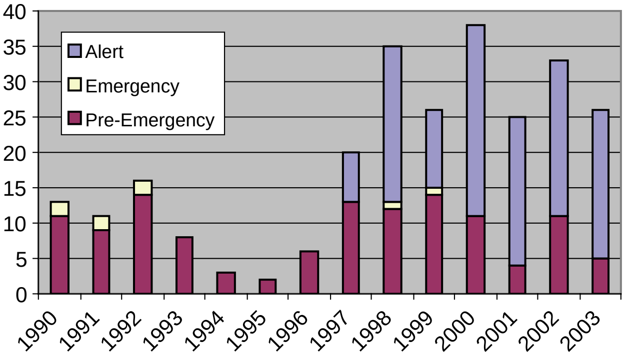

Fig. 2. Number of events in the Santiago Metropolitan Region Air Monitoring System. Note: Alert was established in 1997. Source: based on SESMA, http://www.sesma.cl.

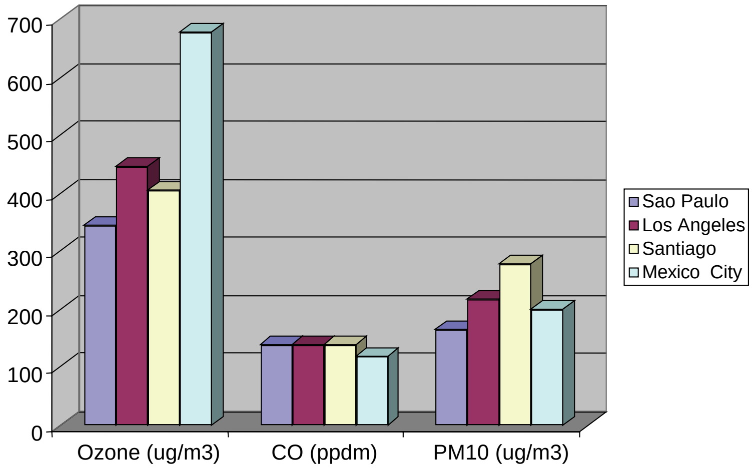

Fig. 3. Comparison of maximum levels of pollution in selected cities (1995–1998). Source: Alliende (2002).

electricity generation. In specific areas, emissions of different pollutants exceed the national norms or international recommendations.

(b) High levels of water pollution caused by domestic and industrial effluents without treatment. This affects surface water, ground water and coastal seawater.

(c) Water scarcity at the regional level.

(d) Inadequate urban development management, high levels of pollution, lack of green or recreational areas, etc.

(e) Inappropriate solid waste management and disposal, particularly hazardous wastes.

(f) Land erosion and degradation, associated to poor agricultural and forestry techniques, urban growth and inadequate solid waste management. This 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 resource overexploitation and biomass exhaustion.

(i) Poor management of hazardous chemical substances.

The rapid and unmanaged urbanization, fueled by economic growth, has led to moderately severe air and water pollution in many of Chile's cities. Preventive costs, health damages and productivity losses, particularly in Santiago, have been significant.

Air pollution in Santiago is the most obvious environmental problem in the country (see Figs. 2 and 3 and Tables 3 and 4), while other cities are also becoming affected (see Table 5). For Santiago, natural variables, demographic growth, and both fixed and

Table 3
Air pollution in Santiago (1995)

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

Source: SESMA, INE.
[a] Data in ppm.
[b] Data in ppb.
[c] Data in μg/m3.
* The annual average is calculated as the annual average per month of all monitoring stations.

Table 4
Air pollution in Santiago (2000)

Pollutant	CO^a	$Ozone^b$	$PM10^c$	$PM10–2.5^c$	$PM2.5^c$	SO_2^c
Max.	19.3	162	230	105	153	135
Min.	0.1	1	5	1	4	1
Average*	1.1	16	87	35.8	34.8	4.7

Source: SESMA, INE.
[a] Data in ppm.
[b] Data in ppb.
[c] Data in μg/m3.
* The annual average is calculated as the annual average per month of all monitoring stations.

Table 5
Summary of air quality in Chile's major cities

City	Region	Exceeds PM10 standard?	Other pollutants with problems?	Main emitting sources
Arica	I	Yearly standard is exceeded	Probably sulfates	No information
Iquique	I	Daily standard was exceeded 8 times and yearly standard exceeded	No	Fixed and mobile sources
Antofagasta	II	Daily standard was exceeded 2 times	Particulates	No information
Calama	II	Daily and yearly standard exceeded	SO_2	Fixed sources
Valparaíso-Viña del Mar	V	Daily standard was exceeded 3 times. Yearly average is very close to being exceeded	NO_2, SO_2, ozone	Mobile sources
Santiago	Metropolitan	Daily standard was exceeded 138 times. Yearly average exceeded	PM2.5, ozone and CO	Streets, vehicles, and industry
Rancagua	VI	Daily standard was exceeded 11 times. Yearly average exceeded	Ozone	Mobile sources
Concepción-Talcahuano	VIII	Daily standard was exceeded 3 times	SO_2	No information
Temuco	IX	Daily standard was exceeded 9 times	No	Fixed sources

Source: Summarized from Universidad de Chile (2002).

mobile air pollution sources are principal causes. The total amount of vehicles in Chile has grown from 1.1 million in 1990 to over 2.1 million by 2000. However, important reductions in PM10 and PM2.5 (23.3% and 46%, respectively) have been achieved since 1989. The decontamination plan, elimination of 3000 highly polluting buses, 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 had converters in 1999) are the main underlying reasons for improvement. In 1999, one emergency event was declared,[10] while there were 14 environmental pre-emergency events (the highest number in the 1990s).

The transport sector contributes the most to air pollution, as it is directly responsible for most of PM10 emissions, the most critical environmental problem in the city: 25% are emitted directly and another 50% resuspended by vehicles on paved and non-paved roads. This sector is also responsible for 50% of PM2.5 emissions. Furthermore, the transport sector is also responsible for 94% of carbon monoxide (CO) emissions, 83% of nitrogen oxides (NO_x) emissions and 42% of volatile organic compounds (VOC) emissions. Private transport is generally more polluting in terms of concentration of pollutants per vehicle mile traveled than public transport, except for PM10 emissions.

However, as air pollution in Santiago is subject to climate variables and pollution strongly varies among seasons, the annual average values can be meaningless.

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 Ozone in Valparaiso-Viña del Mar. The Talcahuano environmental recovery plan is in operation and air monitoring systems are been established in several cities with the goal of identifying saturated zones. Other significant sources of industrial pollution include the use of fossil fuel, in addition to the pulp and paper industry in Regions VII through IX (sulfhydric acid), and fishmeal industry in VIII Region (sulfhydric acid and trimethylamine).

Studies indicate that the most significant effects on human health result from fine particles (PM2.5) in air pollution. As a result, several territories have been declared "saturated areas" for specific pollutants. Santiago Metropolitan Region was declared saturated of PM10, CO_2, O_3 and latent of NO_x in 1996.

[10] 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:

Index	CO (ppm)	SO_2 (μg/m^3)	NO_2 (μg/m^3)	O_3 (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

A compensation system for particulate material from large fixed sources (volumes of up to 1000 m^3/h) has been put into effect for air pollution. Sources emitting less than their goal are able to sell their emitting capacity. Even though the system has been in place for four years, few trades have occurred. Moreover, there is a general 'ideological (rather than technical) debate as to whether this instrument is appropriate in Chile. In addition, public transport route tenders must compete for some of the most important roads used within Santiago. One key parameter considered in assigning these routes is the emission characteristics of vehicles.

The total production of domestic waste is also growing rapidly in Chile and is unevenly distributed within the Metropolitan Region, generating 60% of domestic waste, while housing only 40% of the population.

Water pollution is another problem for the country, together with severe *water scarcity*, which occurs in the northern regions and the Central Valley. Factors such as demographic growth, industrialization and concentration of urban areas have contributed to the deterioration of water volumes and its environment. The problem is most serious in the north (mainly due to fishing and mining activities), the metropolitan region of Santiago and the central seaboard (sewage and industrial pollution) and coastal areas (Bay of Talcahuano—fisheries, petroleum and pulp industries), whereas the south experiences the setback of periodic flooding.

Studies show that the main water quality issue is microbiological contamination. While sanitation services are quite well developed in Chile, the *disposal* of collected wastewater is inadequate. Waste treatment facilities are few and centred in Santiago. Rivers are particularly affected by the dumping of untreated sewage into open watercourses.

Water pollution due to agricultural runoff is a concern, although limited information is available on the problem. The use of water for agricultural, forestry and aquacultural purposes, as well as the increase in human effluents into the lakes in southern Chile has significantly increased the growth of nutrients (acting as pollutants) in these water systems, resulting in a build-up of algae and a drop in biodiversity.

Centralization is also a problem which can hamper efficient regulation. Although decentralization efforts have been made, management of environmental policy in Chile tends to be concentrated in the center, with little concern for regional development priorities.

In conclusion, water and air pollution remain as important problems in Chile despite the increasing environmental expenditures, both public and private. The same is true for social issues. Remedies require both new policies to address environmental and social concerns, and improvement in the monitoring and enforcement of such measures. The next chapter assesses the cross effects of social and environmental policies in Chile.

3. Cross effects of social and environmental policies in Chile

From the previous sections, it can be concluded that there are many environmental problems that need to be tackled, particularly air pollution. Social issues are also a key concern and will continue to be in the next decade. Where should Chile start? Are there significant negative interactions or positive synergies between environmental and social policies? This paper seeks to analyze the links between environmental policies and their respective social effects, and alternatively the impact of social policies on environment.

We first simulate an environmental policy: reduction by 10% of PM10 emissions through an emission tax. The same is done for SO_2 and NO_2 emissions. We then analyze the impacts on economic, environmental and social variables, deciding which environmental policy/taxation is more effective. The second step establishes the impact of a social policy, by simulating an increase in government transfers to households and analyzing its economic, social and environmental effects. Finally, we simulate both policies simultaneously, while maintaining public savings constant, in order to illustrate the interrelations of both policies (knowing their individual impacts). Sometimes, by combining different policies we may not achieve a simple superposition of their individual expected effects. Alternatively, in other cases, we may enhance the objective of one policy by applying a second one. To carry out our analysis, we use the ECOGEM-Chile model, a CGE model for Chile adapted from an OECD CGE model (Beghin et al., 1996).[11] This CGE model is a static model characterized by multiple sectors, two kinds of labour, quintiles of income, an external sector and specified productive factors, among other features. The model is savings-driven and includes energy-input substitution to reduce emissions, as emissions are related to the use of different inputs and not only to production levels.

The main source of information is the 1996 Chilean social accounting matrix (SAM), which was built for this application based on the most recently available input/output matrix for 1996 (Banco Central de Chile, 2001). It is denominated in billions of pesos at 1996 purchasing power (O'Ryan et al., 2001).

We assume zero capital mobility across sectors, pressing for intrasectoral adjustment in a short-run context. As for the income, substitution and other elasticities, it is possible to choose long-term elasticities provided by the relevant international literature, giving 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 due to the static nature of the model, and long-term elasticities will only minimize this flaw. With these parameters, the scenarios modeled here should account for medium term effects. Although full employment is assumed, we also create a scenario that analyzes the effects of high unemployment.

There are two types of emission coefficients: input-based and output coefficients. 13 different pollutants are identified. Toxic effluents are segregated by medium: air, water and soil (TOXAIR, TOXWAT, TOXSOIL). They contain mineral and industrial chemicals, fertilizers and pesticides, paints, etc. Bio-accumulative pollutants are also segregated by medium: air, water and soil (BIOAIR, BIOWAT, BIOSOIL). They contain metal elements such as aluminum, arsenic, copper, lead, mercury, zinc, etc. and they have a significant long-term risk to life. Other air pollutants include: SO_2, NO_2, VOC (volatile organic compounds), CO and PM10. Other water pollutants include: BOD (biological oxygen demand) and TSS (total suspended solids).[12]

3.1. Environmental policy

We analyze the impacts of a 10% reduction in PM10 emissions by using emission taxes (the main target of the air-related environmental policy in Chile). This level of reduction is easily achieved without high abatement costs, compatible with the current economic context of high unemployment in Chile. Furthermore, expected revenues associated with environmental taxes are similar to the financial requirements for the employment policy. We replicate the same exercise for NO_2 and SO_2 emissions looking for efficiency gains and enhancing positive results (reducing negative ones). Apart from causing acid rain, NO_2 and SO_2 are the main chemical components of PM2.5—the fine fraction included in PM10 that causes most health problems.[13] Higher public revenues are not compensated, leading to increased public savings. Therefore, new taxation appears in the economy without any other taxation/subsidy compensation. The results on macroeconomic variables are presented in Table 6.

All results show moderate impacts on macro-variables despite the adjustment process that follows environmental taxation. Real GDP and consumption are moderately reduced, concurrent with reductions in exports and imports, which are close to 1%.

Some significant sectoral impacts can be observed in Table 7. Emission taxes increase bill collection, raising public savings by around 14%. Despite household and enterprise savings (marginal) reduction, global savings rise. Increases in savings drives investment growth, which is channeled to the economy mainly through the construction sector, increasing the sectors output by 0.7%. The electricity sector also marginally benefits from these policies since part of energy demand is substituted from oil

[11] See Appendix A for more detail. The complete set of equations is available upon request.

[12] Emission coefficients are obtained from Dessus et al. (1994).

[13] The levels of PM, SO_2 and NO_x in a number of megacities have been compared by The World Bank, where the pollution levels are above the limiting values recommended by the WHO guidelines (90 $\mu g/m^3$, 50 $\mu g/m^3$ and 40 $\mu g/m^3$, respectively).

Table 6
Macroeconomic impacts of environmental taxation

Taxation on	PM10	SO_2	NO_2
Real GDP	−0.2% [−0.1%]	−0.2%	−0.2%
Investment	0.8% [0.9%]	0.6%	0.7%
Consumption	−0.6% [−0.5%]	−0.5%	−0.6%
Exports	−1.1% [−1.0%]	−1.0%	−1.0%
Imports	−1.0% [−0.9%]	−0.9%	−0.9%

Note: Results for PM10 simulation in a context of high unemployment are presented in brackets.

and gas towards electricity (−0.1–0.3%). Transport, oil and gas extraction, and oil refining suffer the highest negative impact in these simulations, reducing their sectoral output by 2.1–2.3%, 4.1–4.3% and 9.7–9.8%, respectively. Impacts on other sector are negligible.

From an environmental point of view, Table 8 and Fig. 4 show that almost all emissions can be reduced by taxing PM10 emissions, with the sole exception of bio-accumulative effluents into water, which increase marginally due to improvements in the construction sector. Furthermore, NO_2 and SO_2 emissions are reduced by over 10% when taxing PM10. The latter indicates strong links between different pollutants, especially among air pollutants. Taxing PM10 also shows greater positive environmental impacts than SO_2 or NO_2 taxation. The latter presents some increments on water effluents due to sectoral re-accommodation of production (Table 9).

Vis-à-vis social effects, the simulations show a slight–but not significant–increase in employment (related to the slight decrease in wages). Higher demand for labor in the construction sector, although offset by contractions in other sectors, explains this effect. A more positive effect on employment can be seen when environmental taxation (on PM10) is applied in a high unemployment scenario. This is true because unemployment acts as productive sectors adjustment shield against new taxation.

There is also a moderate negative effect on household incomes, which are reduced by 0.6% for all quintiles–0.5% in the case of high unemployment–when PM10 is taxed. For SO_2 and NO_2 taxation results are similar. Despite the latter, if another welfare measure is used–such as the utility functions–, we can observe that this policy is slightly regressive, as part of the enterprise adjustment to the new environmental taxation is carried out over the labor market (wages reduction) and consumer prices rise, thereby affecting lower income consumption relatively more. This is illustrated in Tables 10 and 11.

Finally, we can observe that environmental policies may have some negative social impacts, especially with regard to welfare. The utility function, which assumes a decreasing marginal utility–consistent with most economic models–, may contribute to the explanation. Nevertheless, all

Table 7
Sectoral Impact of environmental taxation

	PM10	SO_2	NO_2
Construction	0.7% [0.8%]	0.6%	0.6%
Electricity	−0.1% [0.0%]	0.3%	0.3%
Renewable resources	−0.7% [−0.6%]	−0.6%	−0.6%
Wood products	−0.7% [−0.6%]	−0.6%	−0.6%
Gas	−0.8% [−0.7%]	−0.8%	−0.8%
Load and pass tpt.	−2.2% [−2.1%]	−2.1%	−2.1%
Other transport	−2.3% [−2.1%]	−2.2%	−2.2%
Oil and gas extraction	−4.1% [−4.0%]	−4.3%	−4.3%
Coal	−5.2% [−5.0%]	1.1%	1.1%
Oil refinery	−9.7% [−9.6%]	−9.8%	−9.8%

Note: Results for PM10 simulation in a context of high unemployment are presented in brackets.

Table 8
Environmental impact of environmental taxation

	10% reduction of PM10	10% reduction of SO_2	10% reduction of NO_2
TOXAIR	−0.6%	−0.6%	−0.6%
TOXWAT	−1.0%	−0.9%	−1.0%
TOXSOIL	−0.4%	−0.4%	−0.4%
BIOAIR	−1.4%	0.0%	0.0%
BIOWAT	0.2% [0.3%]	0.6%	0.6%
BIOSOIL	−0.4%	−0.4%	−0.4%
SO_2	−10.1%	−10.0%	−10.2%
NO_2	−10.0% [−9.9%]	−9.9%	−10.0%
CO	−9.5%	−3.5%	−3.5%
VOC	−1.1% [−1.0%]	−1.0%	−1.1%
PART	−10.0%	−9.3%	−9.4%
BOD	−0.4%	−0.4%	−0.4%
TSS	−8.9% [−8.8%]	2.7%	2.7%

Note: Results for PM10 simulation in a context of high unemployment are presented in brackets when they are different.

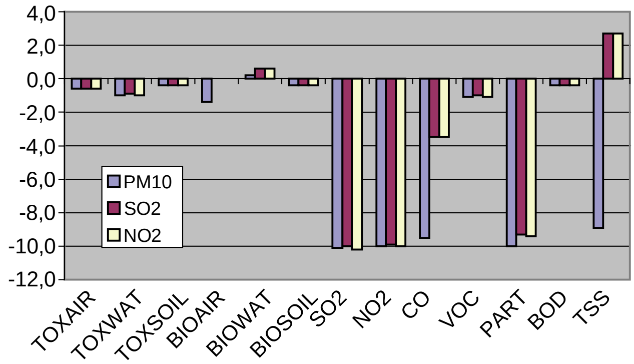

Fig. 4. Environmental impact of environmental taxation. Note: PM10 columns show the impacts on all pollutants when taxing PM10, the same applied for SO_2 and NO_2, respectively.

benefits associated with improvement in environmental quality, such as reduction in health costs, productivity increments, reduction in defensive cost, etc., are not incorporated in the model, thereby overvaluing negative social impacts—and even economic ones.

In conclusion:

1. The choice of pollutant to be taxed is important: Taxation of some specific pollutants can reduce global pollution more effectively than taxing other effluents. A tax on PM10 emission leads to superior environmental results than taxing SO_2 and NO_2, without worse macro, sectoral or social consequences.
2. There are strong links between different pollutants. Therefore, careful assessments can contribute to improve the efficiency and efficacy of the environmental policy.
3. Macro-economic impacts are low and negative, but sectoral effects (positive and negative) can be strong. Therefore: (a) flexible policy should be applied and adjustment periods must be considered; (b) it is important to decide on the use of the revenue arising from the environmental taxation. These new resources can be used to compensate the losers directly or preferably, to reduce/eliminate a distorting tax achieving double dividends. Through careful targeting, tax reforms aimed at taxing bads instead of goods could reduce pollution without economical and social loses.
4. With high unemployment, an environmental tax shock seems to be better absorbed by the economy as the adjustment processes have more degrees of freedom in the short run. Thus, although a sole environmental taxation policy could enhance a negative situation under a crisis/recession context, tax reforms could be better applied.

Table 9
Environmental impact of PM10 taxation

	Total effect	Production effect	Demand effect
TOXAIR	−0.6%	−0.6%	−2.8%
TOXWAT	−1.0%	−0.8%	−6.3%
TOXSOIL	−0.4%	−0.4%	0.0%
BIOAIR	−1.4%	−1.5%	−0.1%
BIOWAT	0.2%	−2.2%	0.7%
BIOSOIL	−0.4%	−0.4%	0.1%
SO_2	−10.1%	−7.8%	−16.5%
NO_2	−10.0%	−7.7%	−16.5%
CO	−9.5%	−8.5%	−16.3%
VOC	−1.1%	−1.3%	−0.0%
PART	−10.0%	−7.8%	−16.5%
BOD	−0.4%	−0.4%	−0.0%
TSS	−8.9%	−8.9%	−10.3%

Table 10
Social impact of environmental taxation

Real disposable income	PM10	SO_2	NO_2
I Quintile	−0.6%	−0.5%	−0.5%
II Quintile	−0.6%	−0.5%	−0.5%
III Quintile	−0.6%	−0.5%	−0.6%
IV Quintile	−0.6%	−0.5%	−0.6%
V Quintile	−0.6%	−0.5%	−0.5%

Table 11
Impacts on utility of taxation on PM10 emissions

	PM10	PM10+unemployment
I Quintile	−0.6%	−0.5%
II Quintile	−0.6%	−0.5%
III Quintile	−0.5%	−0.5%
IV Quintile	−0.5%	−0.4%
V Quintile	−0.2%	−0.2%

3.2. Social policies

The social policy simulated consists of an increase in transfers to households by 8.4%.[14] The resources involved in this increase of transfers is equivalent to the cost of 100,000 new jobs created directly by the government–as the employment plans actually put into practice–, which would reduce actual unemployment from 10% to 8.2%. Currently, public transfers account for 23% of government expenditure; this increment would increase transfers to 25%. Transfer distribution shares among income quintiles are held constant, maintaining their current participation: 1st quintile 27.3%, 2nd quintile 26.6%, 3rd quintile 22.3%, 4th quintile 17.9% and the richest quintile 5.9%. We should note the poor income distribution in Chile, where the richest 10% of the population account for more than 40% of the income, and the next income decile has a share of around 15% (or about US$1600 a month). The increase in government expenditure is not counterbalanced by any additional revenue, thereby reducing government savings.

The macro-effects of this simulation are very minimal. GDP is not affected. Investment falls by almost 1% due to the reduction of government savings (of more than 14%). On the other hand, consumption grows due to higher disposable incomes for almost all households. The construction sector is by far the most negatively affected, due to reduction in investment. The machinery sector is also adversely affected, but it has a very trivial effect. Gas, hydraulic/water, and load and passenger transport sectors benefit slightly from this social policy (Table 12).

Social impacts are positive, with real income for almost all quintiles increasing and the poorest improving the most. Impacts on utility are very similar to those of income distribution.

Finally, in terms of environmental effects, we notice slight increases in some emissions, mainly those connected to air pollution. The demand effect is generally negative for environmental quality, although the production effect–linked to construction slowdown–is positive for the environment. However, all impacts are almost negligible.

In conclusion, this specific social policy has very low impacts on environmental quality, although the sign depends on the specific pollutant.

Table 12
Impacts of a social policy consisting on an increment of transfers to households

Macro-variables	Real GDP	0.0%
	Investment	−0.8%
	Consumption	0.4%
	Exports	−0.1%
	Imports	−0.1%
Sectoral production output	Construction	−0.7%
	Electricity	0.1%
	Renewable resources	0.0%
	Wood products	0.0%
	Gas	0.2%
	Water	0.2%
	Load and pass tpt.	0.2%
	Other transport	0.0%
	Oil and gas extraction	0.0%
	Oil refinery	0.1%
Households real income	Quintile I	3.2%
	Quintile II	1.7%
	Quintile III	1.0%
	Quintile IV	0.4%
	Quintile V	0.0%
Environmental variables emissions	TOXAIR	−0.1%
	TOXWAT	−0.1%
	TOXSOIL	−0.1%
	BIOAIR	−0.1%
	BIOWAT	−0.7%
	BIOSOIL	−0.1%
	SO_2	0.1%
	NO_2	0.1%
	CO	0.1%
	VOC	0.0%
	PART	0.1%
	BOD	−0.1%
	TSS	0.2%

[14] This increment is consistent with the revenues obtained from the emission taxes on PM10 applied in the previous simulation.

Table 13
Comparative macroeconomic impacts

	PM10	Transf.	PM10+transf.
Real GDP	−0.2%	0.0%	−0.2%
Investment	0.8%	−0.8%	−0.1%
Consumption	−0.6%	0.4%	−0.2%
Exports	−1.1%	−0.1%	−1.2%
Imports	−1.0%	−0.1%	−1.1%

3.3. Mixed policies: social and environmental

In the previous exercises, the environmental policy applied did not have major social impacts, and the social policy applied had insignificant impacts on environmental variables. Furthermore, a double dividend (social and environmental) did not exist. However, there seemed to be a trade-off among social and environmental policies/impacts, which could be even larger if stronger policies are applied.

In this section, we investigate the joint social-environmental policies, which mitigate the negative impacts of policies applied independently. The final simulation in this paper is a mix of the two previous policies, i.e., a 10% reduction in PM10 emissions by emission taxes. The additional revenue generated by this tax is used to increase government transfers to households, keeping real government savings constant.

Macro-impacts are a mix of the results of applying social and environmental policies independently. The negative effect on consumption derived from the environmental policy is mitigated; on the other hand, the negative investment effect due to the social policy is offset. Macro-variables suffer from a slightly negative impact (Table 13).

Table 14
Comparative sectoral impacts

	PM10	Transf.	PM10+transf.
Construction	0.7%	−0.7%	−0.1%
Electricity	−0.1%	0.1%	0.0%
Renewable resources	−0.7%	0.0%	−0.6%
Wood products	−0.7%	0.0%	−0.8%
Gas	−0.8%	0.2%	−0.5%
Water	−0.1%	0.2%	0.1%
Load and pass tpt.	−2.2%	0.2%	−2.0%
Other transport	−2.3%	0.0%	−2.3%
Oil and gas extraction	−4.1%	0.0%	−4.1%
Oil refinery	−9.7%	0.1%	−9.6%

Table 15
Comparative social impacts

Real disposable income	PM10	Transf.	PM10+transf.
I Quintile	−0.6%	3.2%	2.6% (2.5%)
II Quintile	−0.6%	1.7%	1.1% (1.1%)
III Quintile	−0.6%	1.0%	0.4% (0.3%)
IV Quintile	−0.6%	0.4%	−0.2% (−0.1%)
V Quintile	−0.6%	0.0%	−0.6% (−0.2%)

Note: Utility levels presented in brackets.

At a sectoral level, environmental taxation maintains its relative importance on impacts, and winners and losers are almost the same as when applying only the environmental policy. Some exceptions are remarkable: renewable resources, coal, food industry, oil refinery, gas, commerce, load and passenger transport, reduce their negative impact, and service and textiles become positive. Construction, as a channel for investment, presents an average result (−0.1) between those obtained with the environmental and the social policy respectively (Table 14).

Social impacts are also very positive: employment increases slightly and income distribution improves. Nevertheless, there is a reduction in real income of the wealthier 40% of the population. In terms of utility, the results are quite similar, but the wealthiest population hardly receives negative impacts (Table 15).

Environmental impacts of the joint environmental–social policy are comparatively much better. Of

Table 16
Comparative environmental impacts

	PM10	Transf.	PM10+transf.
TOXAIR	−0.6%	−0.1%	−0.8%
TOXWAT	−1.0%	−0.1%	−1.1%
TOXSOIL	−0.4%	−0.1%	−0.6%
BIOAIR	−1.4%	−0.1%	−1.5%
BIOWAT	0.2%	−0.7%	−0.4%
BIOSOIL	−0.4%	−0.1%	−0.6%
SO_2	−10.1%	0.1%	−10.1%
NO_2	−10.0%	0.1%	−9.9%
CO	−9.5%	0.1%	−9.5%
VOC	−1.1%	0.0%	−1.0%
PART	−10.0%	0.1%	−10.0%
BOD	−0.4%	−0.1%	−0.6%
TSS	−8.9%	0.2%	−8.8%

the 13 types of effluents, 9 reduce their emissions more than when applying only the environmental policy. In the other 4 cases, mitigation is close to the highest levels achieved by the separate policies (Table 16).

In conclusion, it is better to combine environmental and social policies. Macro and sectoral impacts maintain their effects in the worst scenario, but both social and environmental variables improve even more. Nevertheless, the small cross impacts suggest that policy-makers should focus on environmental/ social policies separately identifying potential losers for later compensation or aside policies.

4. Concluding remarks

During the nineties, Chile made dedicated efforts to improve environmental and social standards. Further improvements will have increasing marginal costs. Therefore, innovative new approaches should be taken; one possibility is to combine different policies so as to enhance positive cross effects or to mitigate the negative side effects of any specific policy.

This paper presents an empirical application of the computable general equilibrium model, ECOGEM-Chile, to assess environmental and social linkages. The model incorporates complex interrelations between the diverse sectors and agents of the economy, which facilitates the analysis of cross effects in environmental and social policies. Six different policies are simulated: three environmental policies that impose taxes on air emissions, aiming to reduce 10% of total PM10, SO_2 and NO_2 emissions, respectively; one social policy that increases government transfers to households; and a mixed social-environmental policy package, where the environmental tax on PM10 and the social transfer policy are simulated simultaneously. In the latter, public savings are maintained constant, i.e., revenues from the environmental policy are allocated to social related fiscal expansion. Finally, the first simulation–PM10 taxation–was replicated in a situation of high unemployment.

In relation to environmental policies, it can be concluded that taxing PM10 emission yields better environmental results than taxing SO_2 and NO_2, without substantial differences in the macro, sectoral or social results. Strong links between different pollutants are indicated, encouraging policy-makers to analyze the pollutant to be taxed more specifically, to achieve optimal results.

Considering the "superior" PM10 environmental policy, the simulation shows that macroeconomic impacts are slightly negative, but sectoral effects (positive and negative) can be strong. Therefore, policy-makers should consider a flexible policy with adjustment periods. Nevertheless, tax reforms aiming to tax environmental bads instead of goods seem to be able to achieve fairly good environmental results without economic and social loses.

Under high unemployment situations, an environmental tax shock seems to be better absorbed by the economy. This is true because firms have more freedom to adjust their production functions through the labor market. Nevertheless, this does not imply that environmental taxation should be applied specifically during periods of economic recession or when labor markets are more flexible.

With regard to the social policy applied, the simulation shows very low impacts on environmental quality, although the sign depends on the specific pollutant. In conclusion, the evidence suggests that environmental policies (such as those applied here) may have social impacts, but not vice versa.

Since cross effects are relatively small, policy-makers should focus on the specific policy under consideration (environmental or social). Nevertheless, social and environmental policy-makers should coordinate among themselves, as it is possible to improve some results by combining both kinds of strategies. Thus, specific social policies may ameliorate negative sectoral and distributive effects of environmental policies, i.e., the mix of policies may improve overall results. In this context, compensating policies for potential losers might increase their acceptance of environmental policies.

These results show that general equilibrium modeling, in this case through the ECOGEM-Chile model, is very useful for analyzing systematically and holistically, different economywide policies and their impact on the Chilean economy. Winners and losers may be identified with the potential magnitude of gains and losses. The results obtained are not all straightforward, i.e., indirect effects are relevant.

5. Uncited references

CEPAL, 2002
CONAMA, 1998
CONAMA, 1999
INE, 1995, 1998, 2001
MIDEPLAN, 1999a
MINEDUC (Ministerio de Educación), 1999
MINVU (Ministerio de Vivienda y Urbanismo), 1999
O'Ryan et al., 2000
World Bank, 1994

Acknowledgements

The authors would like to thank the World Bank, FONDECYT Project 1020612 and the Munasinghe Institute for Development (MIND) for supporting this research. They are also grateful to Yvani Deraniyagala of MIND for help in preparing this paper.

Appendix A. Summary of the computable general equilibrium model: ECOGEM-Chile

A.1. Characteristics of the model

Here, only the main equations of the model are presented, particularly those associated with environmental variables. The main indexes 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

A.1.1. Production

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:

$$\min \quad PKEL_i KEL_i + PABND_i ABND_i \quad \text{s.t.}$$

$$XP_i = \left[a_{\mathrm{kel},i} KEL_i^{\rho_i^p} + a_{\mathrm{abnd},i} ABND_i^{\rho_i^p} \right]^{l/\rho_p^i}$$

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

A.1.2. Income distribution

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

A.1.3. Consumption

Households distribute their income between saving and consumption through an ELES utility function (extended linear expenditure system).[15] This function also incorporates the minimum subsistence consumption as independent from the level of income.

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

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

Where U is the consumer utility, C_i is the consumption of good i, θ is the subsistence consumption, S is saving, cpi is the price of savings and μ is the

[15] 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.

consumption marginal propensity for each good and to save.

A.1.4. 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 are defined as a fixed share of total final demand.

A.1.5. Public finances

Regarding public finances, there are different types of taxes and transfers according with the Chilean system. The following are defined in the model: direct taxation as labor tax (differentiated by occupational category), taxes on firms and on income (differentiated by quintile). Also import tariffs and subsidies are defined, together with export taxes and subsidies (by sector), a value added tax VAT (for domestic and imported goods, and by sector) and some specific taxes.

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

A.1.6. 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. The domestic supply gets a similar treatment, modeled by a CET function to distinguish between domestic market and exports.

For imports:

$$\min \quad \mathrm{PDXD} + \mathrm{PMXM} \ \text{ subject to}$$

$$XA = \left[a_d \mathrm{XD}^{\rho} + a_m \mathrm{XM}^{\rho}\right]^{l/\rho}$$

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:

$$\max \ \mathrm{PDXD} + \mathrm{PEES} \ \text{ subject to}$$

$$XP = \left[\gamma_d XD + \gamma_e \mathrm{ES}^{\lambda}\right]^{l/\lambda}$$

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.

A.1.7. 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, which may or may not have sector mobility depending on the imposed elasticity.

Short-term or long-term elasticities could be chosen 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.

A.1.8. 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 Walras law.

A.2. Reduction of emissions in the model ECOGEM-Chile

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 most traditional and common one in general equilibrium models is the reduction in the production of the very pollutant sectors. The second 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. Allowing to substitute towards less contaminating energy-inputs, emissions could be reduced. Finally, emissions would be reduced by introducing "end of pipe" technologies (e.g., filters, treatment plants and the like). The latter possibility is in an experimental stage and will not be included in the results of our simulations.

Not included is the possibility of technological change–from investment processes based on relative returns–towards environmental friendly technologies, because it would be necessary to use a dynamic model. Although it is possible to change substitution elasticities to simulate more flexibility to adapt technologies to less polluting processes based on cleaner inputs. Additionally, the consumers' utility function does not include the environmental quality as a good for which there is a willingness to pay (which may alter consumption decisions on the rest of the goods and their equilibrium prices).

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. Those emission factors link the use of each money unit spent in the input with 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:

$$E_p = \sum_i v_i^p \cdot \mathrm{XP}_i + \sum_i \pi_i^p \left(\sum_i \mathrm{XA}p_{ij} + \sum_h \mathrm{XA}c_{ih} + \sum_f \mathrm{XAFD}_f^i \right)$$

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 with the use of polluting inputs, in addition to all the emissions derived from the use of polluting intermediate inputs[16] in the productive processes of all the sectors, in their consumption by households h and by other components of the final demand f.

[16] Not only energy-producing.

References

Adelman, I., Robinson, S., 1978. Income distribution policy in developing countries. Standford University, California.

Adkins, L.G., Garbaccio, R.F., 1999. "A Bibliography of CGE Models Applied to Environmental Issues"; US Environmental Protection Agency, Office of Policy, Office of Economy and Environment, May.

Alliende, F., 2002. "Estudio de caso completo basado en el Plan de Descontaminación de la Región Metropolitana", Taller instrumentos de mercado y fuentes de financiamiento para el desarrollo sostenible, División de desarrollo sostenible y asentamientos humanos, CEPAL, Santiago de Chile, 24 de octubre de 2002.

Auerbach, A., 1985. The theory of excess burden and optimal taxation. In: Auerbach y, A.J., Feldstein, M. (Eds.), Handbook of Public Economics, vol. 1. North Holland, Amsterdam.

Banco Central de Chile, 2001. Matriz de Insumo-Producto de la Economía Chilena 1996. Santiago, Chile.

Barcena, A., De Miguel, C.J., Núnez, G., Gómez, J.J, Acquatella, J., Acuña, A., 2002. Financing for sustainable development in Latin America and the Caribbean: from Monterrey to Johannesburg. World Summit on Sustainable Development, Johannesburg 2002, ECLAC-UNDP, LC/R.2098, August.

Baytelman, Y., Cowan, K., De Gregorio, J., González, P., 1999. "Política Económica-Social y Bienestar: El Caso de Chile", Documento preparado para proyecto de UNICEF.

Beghin, J., Dessus, S., 1999. "Double Dividend with Trade Distortions. Analytical Results and Evidence from Chile", mimeo.

Beghin, J., Dessus S., Roland-Holst, D., Van der Mensbrugghe, D., 1996. "General Equilibrium Modelling of Trade and The Environment", Technical Paper, N° 116, Paris, OECD Development Center.

Beghin, J., Bowland, B., Dessus, S., Roland-Holst, D., Van der Mensbrugghe, D., 2002. Trade integration, environmental degradation and public health in Chile: assessing the linkages. Environment and Development Economics 7 (2), 241–267 (May 2002).

Bento, A.M., Rajkumar, A.S., 1998. Rethinking the nature of the double dividend debate? Documento presentado en "World Congress of Environmental and Resource Economists", Venecia, Italia, 25–27 de Junio, 1998.

Bergman, Lars, 1991. General equilibrium effect of environmental policy: a CGE modeling approach. Environmental and Resource Economics 1, 43–61.

Bosello, F., Carraro, C., Galeotti, M., 1998. The double dividend issue: modeling strategies and empirical findings. Paper presented at the Symposium on "Envirnoment, Energy, Economy. A Sustainable Development", October 1998, Rome.

Bovemberg, L., De Mooij, R., 1994. Evironmental levies and distorsionary taxation. American Economic Review 84, 1085–1089.

Bovemberg, L., Goulder, L.H., 1996. Optimal taxation in the presence of other taxes: general equilibrium analyses. American Economic Review 86, 985–1000.

Brzovic, F., Miller, S., Lagos, C. (2002), "Gasto, inversión y financiamiento para el desarrollo sostenible en Chile" Serie medio ambiente y desarrollo No 57, División de desarrollo sostenible y asentamientos humanos, CEPAL, diciembre.
Bussolo, M., Mizala, A., Romaguera, P., 1998. Beyond Heckscher-Ohlin: trade and labour market, interactions in a case study for Chile. Serie Documentos de Trabajo. FEDESARROLLO. Agosto.
CEPAL, 1999. Panorama social en América Latina 1998. Naciones Unidas, Santiago de Chile. LC/G. 2050-P.
CEPAL, 2000. Panorama social en América Latina 1999/2000. Naciones Unidas, Santiago de Chile. LC/G. 2068-P.
CEPAL, 2002. Globalización y Desarrollo. Vigésimonoveno periodo de Sesiones, Brasilia, Brasil, 6 al 10 de mayo del 2002.
Coeymans, J.E., Larraín, F., 1994. Efectos de un Acuerdo de libre comercio entre Chile y Estados Unido: un enfoque de equilibrio general. Cuadernos de Economía 31 (94), 357–399.
CONAMA, 1998. Plan de Prevención y Descontaminación Atmosférica de la Región Metropolitana 1997. Santiago.
CONAMA, 1999. Memoria Anual 1999. Santiago, Chile.
Conrad, 1999. Computable general equilibrium models for environmental economics and policy analysis. In: van den Bergh, J. (Ed.), The handbook of environmental and resource economics. Edward Elgar Publishing.
De Miguel, C., Miller, S., 1998. Macroeconomía, medio ambiente, y modelos de equilibrio general. Documento de Trabajo. Programa de Desarrollo Sustentable, Centro de Análisis de Políticas Públicas, Universidad de Chile, Santiago. Noviembre 1998.
Dessus, S., Bussolo, M., 1996. Is there a trade-off between trade liberalization and pollution abatement in Costa Rica? A computable general equilibrium assessment. OECD Development Centre. February.
Dessus, S., Roland-Holst, D., van der Mensbrugghe, D., 1994. Input-based pollution estimates for environmental assessment in developing countries. Technical Paper N° 101, Paris, OECD Development Center.
Devarajan, S., 1997. Can computable general-equilibrium models shed light on the environmental problems of developing countries. In: Dasgupta, P.y K.-G. Maler (Eds.), The Environment and Emerging Development Issues, vol. 1. Clarendon Press, Oxford.
DIPRES, 2001. Estadísticas de las Finanzas Públicas 1991–2000. Series Estadísticas, Dirección de Presupuestos, Ministerio de Hacienda, Gobierno de Chile.
Dufournaud, M., Harrington, J., Rogers, P., 1988. Leontief's environmental repercussions and the economic structure revisited: a general equilibrium formulation. Geographical Analysis 20 (4), 318–327.
Edwards, T. Huw, Hutton, John P., 2001. Allocation of carbon permits within a country: a general equilibrium analysis of the United Kingdom. Energy Economics 23 (4), 371–386 (Kidlington, Jul 2001).
FOCUS Estudios y Consultarías, 2000. Presupuesto Nacional Ambiental 1999–2000. Comisión Nacional de Medio Ambiente, Santiago, Chile.
Forsund, F., Storm, S., 1988. Environmental economics and management: pollution and natural resources. Croom Helm Press, New York.
FOSIS, 1997. Proyecto de Presupuesto 1998.
Fullerton, D., Metcalf, G.E., 1997. Environmental taxes and the double-dividend hypothesis: did you really expected something for nothing? NBER Working Paper 6199 (September).
González, P., 1999. "Reforma del Sistema Escolar en Chile", mimeo.
Grossman, G., Krueger, A., 1993. Environmental impacts of a North American free trade agreement. In: Peter, Garber (Ed.), The Mexico–US Free Trade Agreement. The MIT Press, Cambridge.
Gunning, J., Keyser, M., 1993. Applied general equilibrium models for policy analysis. Srinivisan y Jere Behrman, T.N. Handbook of Development Economics, vol. III. North-Holland, Amsterdam.
Harrison, G., Rutherford, T.F., Tarr, D.G., 1997. Opciones de Política Comercial para Chile: una evaluación cuantitativa. Cuadernos de Economía 31.
Harrison, G., Rutherford, T.F., Tarr, D.G., 2002. Chile's regional arrangements: the importance of market access and lowering the tariff to six percent. Prepared for the Central Bank of Chile conference on General Equilibrium Models for the Chilean Economy, Santiago, April 4/5, 2002.
Hazilla, M., Koop, R., 1990. Social cost of environmental quality regulations: a general equilibrium analysis. Journal of Policy Modeling 98 (4), 853–873.
Hertel, T.W. (Ed.), Global Trade Analysis: Modeling and Applications. Cambridge University Press.
Holand, Figueroa, D.E., Alvarez, R., Gilbert, J., 2002. Imperfect labor mobility, urban unemployment and agricultural trade reforms in Chile. Prepared for the Central Bank of Chile conference on General Equilibrium Models for the Chilean Economy, Santiago, April 4/5, 2002.
Ianchovichina, Darwin, E.R., Shoemaker, R., 2001. Resource use and technological progress in agriculture: a dynamic general equilibrium analysis. Ecological Economics 38, 275–291.
INE, 1995, 1998, 2001. Compendio Estadístico, Instituto Nacional de Estadística, Chile.
Jaeger, W.K., 1999. Double dividend reconsidered. Paper presented at "EAERE Ninth Annual Conference", Oslo, Norway, 25–27 June, 1999.
Johansen, L., 1960. A Multisector Study of Economic Growth. North-Holland, Amsterdam.
Jorgenson, D.W., Wilcoxen, P., 1990. Intertemporal general equilibrium modeling of U.S. environmental regulation. Journal of Policy Modeling 12 (4), 715–744.
Jorgenson, D.W., Wilcoxen, P., 1993. Reducing U.S. carbon dioxide emissions: an assessment of different instruments. Journal of Policy Modeling 15 (5), 491–520.
Koskela, E., Schöb, R., Sinn, H., 1999. Green tax reform and competitiveness. NBER Working Paper 6922 (February).
Li, P., Rose, A., 1995. Global Warming and the Pennsylvania Economy: A Computable General Equilibrium Analysis, unpublished paper, MIT.
Lucas, R., Wheeler, D., Hettige, H., 1992. Economic development, environmental regulation and the international migration of

toxic industrial pollution: 1960–1988. In: Patrick, Low (Ed.), International trade and the environment, World Bank Discussion Paper, vol. 159, pp. 67–88. Washington, DC.

Madrid-Aris, M.E., 1998. International trade and the environment: evidence from the North America Free Trade Agreement (NAFTA). Presentado en "World Congress of Environmental and Resources Economics", Venice, Italy, June 25–27.

MIDEPLAN, 1996. Balance Seis Años de las Políticas Sociales: 1990–1996. Santiago de Chile.

MIDEPLAN, 1999a. Indicadores Económicos y Sociales 1990–1998. Documentos. Santiago de Chile.

MIDEPLAN, 1999b. Situación Habitacional en Chile. Resultados Encuesta CASEN 1998. Documento, vol. 6. Santiago de Chile.

MINEDUC (Ministerio de Educación), 1999. Compendio de Información Estadística 1998. Ministerio de Educación, Santiago de Chile.

MINSAL (Ministerio de Salud), 1999. Inversiones Sectoriales en la Década 1990–1999. Ministerio de Salud, Santiago de Chile.

MINTRAB (Ministerio del Trabajo y Previsión Social), 2002. http://www.mintrab.cl.

MINVU (Ministerio de Vivienda y Urbanismo), 1999. Memoria anual, 1999. Ministerio de Vivienda y Urbanismo, Santiago de Chile.

Mukherjee, N., 1996. Water and land in South Africa: economy-wide impacts of reform. Discussion Paper, vol. 12. International Food Policy Research Institute, Washington D.C.

Munasinghe, M., 1992. Environmental economics and sustainable development. Paper presented at the UN Earth Summit, Rio de Janeiro, Brazil, and reproduced as Environment Paper No. 3. World Bank, Wash., DC, USA.

Munasinghe, M., 1994. Sustainomics: a transdisciplinary framework for sustainable development. Keynote Paper, Proc. 50th Anniversary Sessions of the Sri Lanka Assoc. for the Adv. of Science (SLAAS), Colombo, Sri Lanka.

Munasinghe, M. (Ed.) (1996) Environmental Impacts of Macroeconomic and Sectoral Policies, International Society for Ecological Economics and World Bank, Solomons, MD and Wash. DC.

Munasinghe, M., 2002. Macroeconomics and the Environment, The International Library of Critical Writings in Economics, Edward Elgar Publ., London, UK.

Munasinghe, M., Cruz, W., 1994. Economywide policies and the environment: lessons from experience. World Bank, Washington, DC.

Munasinghe, M., O'Ryan, R., Seroa da Motta, R., de Miguel, C., Young, C., Miller, S., Ferraz, C., 2005. Macroeconomic Policies for Sustainable Growth. Edward Elgar Publ., London, UK.

O'Ryan, R., de Miguel, C.J., Miller, S., 2000. World Bank Research Study on Making Long Term Growth More Sustainable. Phase II, Final Report, Universidad de Chile.

O'Ryan, R., de Miguel, C.J., Miller, S., Lagos, C., 2001. "A Social Accounting Matrix for Chile 2001", mimeo.

O'Ryan, R., Miller, S., de Miguel, C.J., 2003. A CGE framework to evaluate policy options for reducing air pollution emissions in Chile. Environment and Development Economics 8, 285–309.

Parry, I.W., Bento, A.M., 1999. Tax deductions, environmental policy, and the "double dividend" hypothesis. World Bank Working Paper Series 2119 (May).

Parry, I.W., Oates, W.E., 1998. Policy analysis in a second-best world. Resources for the Future Discussion Paper Series 98-48 (September).

Persson, A., Munasinghe, M., 1995. Natural resources management and economywide policies in Costa Rica: a computable general equilibrium (CGE) modeling approach. The World Bank Economic Review 9 (2), 259–285.

Pigott, J., Whalley, J., Wigle, J., 1992. International linkages and carbon reduction initiatives. In: Anderson, K., Blackhurst, R. (Eds.), The greening of world trade issues. University of Michigan Press.

Reed, D., 1996. Structural adjustment, the environment and sustainable development. Earthscan Publishers, London, UK.

Repetto, R., Dower, R., Jenkins, R., Geochegan, J., 1992. Green fees: how a tax shift can work for the environment and the economy. World Resources Institute.

Robinson, S., Gelhar, C., 1995. Land, water and agriculture in Egypt: the economy-wide impact of policy reform. Discussion paper. International Food Policy Research Institute, Washington, DC.

Rodríguez, A., Abler, D., Shortle, J., 1997. Indicadores Ambientales en un modelo de equilibrio general computable para Costa Rica. In: Calvo, W., Figueroa, E., Vargas, J.R. (Eds.), Medio Ambiente en Latinoamérica: Desafíos y Propuestas. IICE-CENRE.

Rose, A., Abler, D., 1998. Computable general equilibrium modeling in the integrated assessment of climate change. Presentado en la V Conferencia Bienal de la Sociedad Internacional de Economía Ecológica, Santiago, Chile, Noviembre.

Rose, A., Schluter, G., Wiese, A., 1995. Motor-fuel taxes and household welfare: an applied general equilibrium analysis. Land Economics 71 (2), 229–243.

Ruiz, J., Yarur, I., 1990. "Un modelo de Equilibrio General para Evaluación de Política Tributaria", Tesis para optar al título de Ingeniero Industrial y al grado de Magister en Ciencias de la Ingeniería mención Ingeniería Industrial, Universidad de Chile.

Schkolnik, M., Bonnefoy, J., 1994. "Una Propuesta de Tipología de las Políticas Sociales en Chile", Documento UNICEF.

Taylor, L., 1990. Socially Relevant Policy Analysis: Structuralist CGE Models for the Developing World. The MIT Press, Cambridge.

Taylor, L., Bacha, E., Cardoso, E., Lysy, F., 1980. Models of growth and distribution for Brazil. Oxford University Press, London.

Universidad de Chile, 2002. Informe País. Estado del Medio Ambiente en Chile- 2002, Instituto de Asuntos Públicos-Universidad de Chile, LOM Ediciones.

World Bank, 1994. "Chile, Managing Environmental Problems: Economic Analysis of Selected Issues", Report N° 13061-CH, December 19th.

Yang, Hao-Yen, 2001. Trade liberalization and pollution: a general equilibrium analysis of carbon dioxide emissions in Taiwan. Economic Modelling 18, 435–454.