Trade, Environment, and Public Health in Chile. Evidence from an Economywide Model

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Summary

This paper uses an empirical simulation model to examine links between trade policy, pollution and public health in Chile. Using a general equilibrium framework, we synthesize economic, engineering, and health data in a way that elucidates this complex relationship and can support more coherent policy in all three areas. The basic tool of analysis is a 75-sector calibrated general equilibrium (CGE) model, incorporating monitoring functions for 13 effluent categories and a variety of mortality and morbidity indicators. While the methodology supports more general applications, present attention is confined to atmospheric pollution and health status in the Santiago metropolitan area.

The trade policy scenarios examined include Chile's accession to the NAFTA, MERCOSUR, and unilateral trade liberalization. Unilateral trade liberalization induces substantial worsening of pollution and expansion of resource-based sectors, partly because it facilitates access to cheaper energy. NAFTA integration is environmentally benign in terms of pollution emissions. NAFTA accession, relative to other trade integration scenarios, actually reduces environmental damage. This results because trade diversion reduces reliance on cheap energy, unlike the other two trade integration scenarios.

We find that emissions of small particulates (PM-10), SO_2, and NO_2, have the strongest impact on local mortality and morbidity. These three pollutants appear to be complementary in economic activity. For several types of emissions, accession to the NAFTA appears to be environmentally benign. MERCOSUR and unilateral liberalization have a negative effect on the environment and upon urban morbidity and mortality. Damages due to rising morbidity and mortality are of similar magnitude and substantial. Unilateral trade liberalization induces damages equal to 13 percent of the income gains arising from free trade. Revenue-neutral taxes on air pollutants induce net welfare gains from reduced health damages.

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1 Introduction

The policy significance of trade and environment linkages has increased sharply in recent years, largely because of a higher profile in trade negotiations such as the Uruguay Round and the NAFTA. Among academic observers, a consensus has emerged that trade policy is not an adequate tool for environmental protection (Beghin et al. (1994)), but many other aspects of this linkage remain contentious issues. Unfortunately, there is still relatively little empirical evidence to inform this debate, and this is the main objective of the present paper. In particular, we seek to quantify the direct and indirect effects of environmental taxes, including their revenue, cost, and output effects, as well as their interaction with trade policies and their incidence upon the environment, public health, and elsewhere in the economy. For fast growing developing economies, greater outward-orientation holds great promise in terms of growth and efficiency. Pursuing this goal blindly, however, may jeopardize long-term prosperity because of the environmental costs of such a strategy. Hence, it is essential to assess the environmental impact of trade policy generally and trade liberalization in particular, and to examine how these might be better coordinated with environmental policies to mitigate environmental degradation.

Our paper makes two contributions. Firstly, we explicitly incorporate links from trade to environment to public health indicators, rather than simply measuring pollution incidence or other environmental variables. Secondly, this paper is empirical, and intended to strengthen the basis of evidence for the rapidly evolving policy debate on trade-environment linkages (Beghin and Potier: 1997). The present paper gives empirical evidence for Chile, but the methodology can be extended to other countries. Using an applied general equilibrium model, we investigate the interactions between trade and environmental policies, focusing particularly on trade liberalization and coordinated policies of effluent taxation. We provide estimates of emissions for detailed pollution types at the national level, identifying patterns of pollution intensity that emerge with greater outward orientation. Although we estimate increased intensities for several pollutants when trade liberalization is undertaken without concurrent environmental taxes, none of these is appears alarming.

A second motivation for the present study is to make more tangible the linkages between economic, environmental, and public health indicators, building upon recent and current work on urban pollution and health in Santiago (World Bank (1994); Ostro et. al. (1995); O'Ryan (1994)). This is an essential step in support of policy formulation that takes more explicit account of economy-environment linkages. Past emphasis in this area has been on resource depletion, which is appropriate but seriously limited, since it omits more direct and immediate personal costs of environmental degradation. We quantify the incremental mortality and morbidity associated with combined economic and environmental polices and their monetary damages. Because its topology, local climate, and economic concentration make this urban area comparable to Mexico City and Jakarta, pollution in Santiago poses a major environmental challenge to Chilean policy makers, now and well into the next century.

In this context, we find that abatement of three air pollutants (small particulates, SO_2, and NO_2 (a determinant of ozone)) has the largest impact on mortality and morbidity and far outweighs the health benefits which might arise from abatement of other air pollutants in Santiago. We also find that Chile's accession to the NAFTA, compared to unilateral trade liberalization, would reduce the emissions of many pollutants and have a relatively benign effect on urban public health. Unilateral liberalization, by contrast, would appear to induce a significant transfer of pollution capacity to Chile from the Rest of the World, adversely affecting the environment and public health. Here the case for coordination with environmental policy is compelling indeed.

Until 1975, Chile represented a textbook case of import-substitution, replete with trade distortions, slow growth, foreign exchange restrictions and resulting misallocation of resources. Following a series of policy reforms under the structural adjustment of the 1980s, Chile has become a thriving outward-oriented economy (Papageorgiou et al.; World Bank). Growth of output and exports has been spectacular in natural resource-based industries such as agriculture, fisheries, forestry, and mining sectors in which Chile has traditionally been competitive. These expansions have fostered rising living standards and concerns for the environmental consequences of the resource intensity of the growth (World Bank).

In parallel, urbanization is already well advanced in Chile, where about 85 percent of the population live in or within the vicinity of major cities (for example, Santiago Metropolitan Area and Valparaiso). The income growth and rapid urbanization have outpaced the development of infrastructures such as paved roads, public transportation equipment and sewage treatment systems. Several environmental problems in urban areas are linked to the poor road infrastructure and the use of untreated wastewater used in irrigated agriculture (World Bank (1994)).

The infrastructure problem exacerbates air pollution in Santiago by contributing to emissions of suspended particulates and other effluents in the air. This problem combined with unique topological and climatic conditions (thermal inversion) put Santiago in the league of the most-polluted cities in the world. Rising income and heath concerns are at odds with this situation. With the assistance of international organizations, Chile has started addressing these environmental problems, especially, air and water pollution in Santiago, and the depletion of forest resources (see World Bank (1994)).

A critical mass of information has recently been accumulated on urban pollution in Santiago (O'Ryan (1994); Sanchez (1992); Turner et al. (1993); and World Bank (1994)); we make use of this information when we link national pollution estimates to pollution concentrations in Santiago. Our study is a useful contribution to the existing work on Santiago because it provides estimates of pollution emissions at the national level and of their variations induced by policy changes.

2 The TEQUILA Model

The *Trade and Environment eQUILibrium Analysis* (TEQUILA) model is a prototype computable general equilibrium model developed at the OECD development Centre for research on sustainable development. The full model is described in details in Beghin et al. (1996). The TEQUILA model is recursive dynamic: each period is solved as a static equilibrium problem given an allocation of savings and expenditure on current consumption. It is multi-sectoral (75 sectors for Chile) with careful disaggregation of natural-resource-based sectors and their forward linkages to manufacturing. Natural resource activities include five agricultural sectors, forestry, fisheries, and five mining/extraction sectors. Their linkages to manufacturing are captured by twelve agricultural processing sectors, four wood-based sectors, four oil-based chemical industries, and eight mineral-based ones.

Output is characterized by CRS technology and the structure of production consists of a series of nested CES functions. Final output is determined from the combination of (non-energy) intermediate inputs and a composite bundle of energy and value added (labor, and capital (machinery and land)). Non-energy intermediate inputs are assumed to be utilized in fixed proportions with respect to total non-energy intermediate demand. The energy-value-added bundle is further decomposed into a labor aggregate, and a capital-energy bundle. Labor demand is further decomposed into ten occupations. The capital-energy bundle is further disaggregated into capital demand and demand for an energy aggregate. The energy bundle is itself decomposed into four base fuel components. In this production structure, emissions are linked to intermediate consumption (inputs) rather than final output. Figure 1 shows the nested structure of production.

Most existing CGE models investigating pollution issues assume fixed proportion between sectoral output and emissions associated with that sector. By contrast, we posit substitution possibilities between value added, energy and non-energy intermediate goods, which allow the decrease of pollution associated with production if pollution taxes are put in place. This is a major improvement in the incorporation of pollution in economywide modeling.

We econometrically estimate the pollution effluents by sector as being function of energy and input use (Dessus et al.). Estimates of these input-based effluents intensities are obtained by matching data from a social accounting matrix disaggregated at the 4-digit ISIC level to the corresponding IPPS pollution database of The World Bank (Martin et al.). Emissions are generated by both the final consumption and the intermediate use of polluting goods. Excise/effluent taxes are used to achieve pollution abatement. These taxes are measured as unit of currency per unit of emissions and are uniform taxes *per unit of effluent* for all sectors. Since every sector has different effluent intensities, the pollution tax, expressed *per unit of output*, varies across sectors. The latter taxes are tacked on to the producer price of the polluting commodity.

Pollution by sector is characterized by a vector of 13 measures of various water, air and soil effluents. Pollution intensity varies by sector and with relative prices, since the use of “dirty” inputs is influenced by relative price changes induced by policy intervention. The 13 pollution measures include: toxic pollutants in water, air and land (TOXAIR, TOXWAT, TOXSOL); bio-accumulative toxic metals in air, soil, and water (BIOAIR, BIOWAT, BIOSOL); air pollutants such as SO_2, NO_2, CO_2, volatile organic compounds (VOC), and particulate intensity (PART); and finally, water pollution measured by biological oxygen demand (BOD), and total suspended solids (TSS).

We calibrate the TEQUILA model using a detailed social accounting matrix of Chile for 1992. The model is neoclassical with all markets reaching equilibrium. Trade is modeled assuming goods are differentiated with respect to region of origin and destination. On the import side, we account for the heterogeneity of imports and domestic goods with the CES specification attributed to Armington. We assume a CET specification for domestic output, in which producers are assumed to differentiate between the domestic and export markets. We assume that Chile is a small country. Trade distortions are expressed as *ad valorem* tariffs. This assumption is consistent with the recent tariffication of most trade distortions in Chile following its structural reforms.

3 A Brief Description of The Santiago Health Model[2]

This section briefly describes how we map predicted pollution emissions from our simulations into health effects for residents of Santiago and then ascribe monetary damages to health impacts of pollution. In summary, the model estimates the change in health status associated with a change in major air pollutants by each of 72 industrial activities in Santiago. Changes in industry emissions used are obtained from the economywide model. The health effects model transforms these emissions data into corresponding changes in health status (e.g., reduction in PM-10 related mortality). In so doing, the health effects component is used to estimate the potential health damage savings (costs) corresponding to alternative trade and environment policy scenarios analyzed by the economywide model.

In characterizing emissions, we use baseline information on major air pollutants and emission sources. This step involves collecting data on pollutants known to cause significant

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[2] The health-module for Santiago is formally presented in Bowland (1997), which describes in full details the different steps and issues involved in the derivation of pollution concentration in Santiago, health impact and monetary damages.

health problems in Santiago, the corresponding emission sources, and baseline average annual emissions and ambient concentration levels. The data are used to estimate the portion of economywide emissions attributable to Santiago, as well as calibrate the health module of the CGE model to initial conditions.

Dispersion modeling maps effluent emissions into ambient concentration levels, and population-weighted concentration levels are used to determine exposure rates for health impacts. The next step involves calculating the health status response to changes in concentrations of air pollutants. Dose response functions express the change in incidence of mortality/morbidity induced by changes in pollution concentrations (Ostro et al.:1995). The figures on health end-points presented in the results section should be interpreted as increases or decreases in mortality and morbidity with respect to the mortality and morbidity that would have prevailed at a predetermined safe standard of pollution concentrations. We look at various morbidity and mortality indicators:

1. Premature mortality due to PM-10, SO_2, and ozone
2. Premature mortality in males of age 40-59 due to lead
3. Respiratory hospital admissions (for PM-10, ozone)
4. Emergency room visit (for PM-10)
5. Restricted activity days (for PM-10)
6. Lower respiratory illness for children population of age less than 17 (PM-10)
7. Asthma symptoms for asthmatic population (for PM-10, ozone)
8. Respiratory symptoms (for PM-10, ozone)
9. Chronic bronchitis in population of age 25 or older (for PM-10)
10. Minor restricted activity days (for ozone)
11. Respiratory symptoms in children population (for SO_2)
12. Chest discomfort in adult population (for SO_2)
13. Respiratory symptoms in adult population (for NO_2)
14. Eye irritation in adult population (for ozone)
15. Number of headache in adult population (for CO)
16. IQ decrement in children population (for lead)
17. Cases of hypertension in adult male population (for lead)
18. Non-fatal heart attacks in male population age 40-59 (for lead)

The last step is to attach a monetary value to the health impact figures. We follow a willingness-to-pay approach to valuing morbidity and loss of life due to a change in mortality, relying on the large body of information and data on such measures for industrialized economies to econometrically estimate these damages for Chile. Damages due to mortality are based on the value of a statistical life, which indicates the aggregate valuation by individuals of reducing the risk of dying. For Santiago, our estimate is roughly .55 million dollars per life, in 1992 (purchasing power parity) US dollars. This estimate corresponds to the value of a life reached in 2010 under the reference business-as-usual scenario (Bowland:1997).

Because of the scarcity of corresponding morbidity estimates available for industrialized countries, our morbidity willingness-to-pay measures are less sophisticated. Available estimates from industrialized countries were simply scaled down to reflect the per capita income differences between Chile and these industrialized countries, expressed in (PPP) 1992 US dollars.

4 Policy Reform Scenarios

The time horizon of the simulations is the period 1992-2010. Every year, savings determine the pool of new investment resources for the *next* period and the model solves for an equilibrium. This equilibrium determines savings going to the new investment pool for the subsequent period. Each period, sectoral resource allocation adjusts to new prices. Labor moves freely across sectors; existing capital is reallocated across sectors, but to a lesser extent due to a partial mobility (vintage capital) assumption in the model. The endogenous variables of interest, which adjust at every period, are sectoral inputs, factor use, and output, consumption, trade, pollution emissions associated with production and consumption. Aggregate real income serves as an approximate gauge of welfare or economic efficiency. We do not attempt to measure the cost of pollution and characterize “externalities” only by the level of pollution emissions estimated in each scenario.

We first define a reference trajectory for the economy based on DRI-McGraw-Hill predictions of GDP growth until 2010. Factor and energy productivity changes are endogenously determined such that the GDP forecast and the model are consistent with each other. All policies are held constant in this reference scenario, called the business-as-usual (BAU) scenario. For the years 1992 to 2010, the model gives us reference trajectory base for output, absorption, trade, and pollution emissions, for this BAU scenario. This is the base or reference trajectory of the economy for our analysis. All reported results are expressed in deviations (in percent) from this BAU scenario and for 2010, which is the final year of the simulation exercise.

The first reform scenario imposes taxes on pollutants, one at the time[3]. Each tax is such that the emissions of the targeted pollutant progressively decrease over time and reach a 25 percent decrease relative to its level in the BAU results by 2010. The phasing in of these taxes is set to obtain gradual reductions of 10 percent in 1995, 15 percent in 2000, 20 percent in 2005, and 25 percent in 2010. The tax rates per unit of effluent are the shadow prices of the quantitative constraints on the pollution emissions.

The second scenario considers a gradual trade integration, combining unilateral trade liberalization through tariff reductions, with a concurrent but modest improvement of terms of trade. Terms of trade are parametric for Chile, assumed to be a small country, and the terms of trade improvement is introduced as an exogenous shock. We assume that export prices increase to simulate this improvement that should result from the integration of trading countries. This is equivalent to an improvement of the terms of trade. We decrease the ad-valorem tariffs, progressively to free trade, from their reference levels (1992) as 90 percent of original tariffs in 1995, 60 percent in 2000, 30 percent in 2005, and no tariff in 2010. Terms-of-trade improvements are expressed as an increase in observed world prices for exports by 2 percent in 1995, 4 percent in 2000, 7 percent in 2005, and 10 percent in 2010. The terms-of-trade assumption allows us to see how the environment is affected by an outward-oriented growth strategy.

We consider analogous regional integration and liberalization scenarios with NAFTA and MERCOSUR countries. Disaggregated data on trade flows allow us to consider these alternative trade liberalization scenarios. In these two other trade scenarios, we remove tariffs and increase export prices following a similar progression as in the previous scenario, but only with respect to trading partners which are members of these two regional agreements. Our objective is to impose a sizable trade shock on the Chilean economy to estimate changes in sectoral composition of production and trade. These changes determine the pollution emitted and induced by the outward trade orientation.

The last group of reform scenarios combines the first two types of reforms. For this last scenario, the objective is to investigate the implications of coordinated trade and environment policies. Analytical results (Copeland; and Beghin et al. (1997)) imply that the coordinated piecemeal approach -gradual changes of two instruments to correct for trade and environmental distortions- leads to welfare improvements. In the context of joint trade and environmental reforms, efficiency gains are obtained because trade distortions are reduced and because environmental degradation can be reduced as well. Recall we want to investigate the effect of such joint reform on sectoral allocation, trade, and pollution abatement. Free trade removes border distortions (domestic border prices are equal to world prices) and the incentives to change input mixes to abate pollution in production have been altered, compared to the case of the single environmental reform. The differences in the incentive structures lead one to expect contrasting results concerning the indirect abatement achieved via complementarity and substitution among emission types, which occurs under the two scenarios.

5 Results from Policy Reform Simulations

Results follow the sequence of the three reform scenarios: environmental tax reform, trade integration (unilateral liberalization, NAFTA, and MERCOSUR), and then combined trade integration and environmental protection. Results are presented for the final year, 2010, in percent deviations from their BAU values. Table 1 summarizes the salient results of the simulations in aggregate. Table 2 shows the effects of the various scenarios on pollution emissions. A longer report is available upon request. We first note some stylized facts emerging from the Social Accounting Matrix on sectors which appear to be pollution hot-spots in Chile. The following sectors exhibit high intensities and levels for several effluent types: agriculture, sugar refining, mining, chemicals, metals, pottery, electricity, gas, and transportation sectors.

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[3] Taxing all pollutants simultaneously, raises difficulties. First, tracing the effect of any single tax on resource allocation becomes impossible. Second several tax combinations lead to the same decrease in all pollutants, but with different implications on sectoral allocation, consumption and trade.

5.1 Effluent taxes

Effluent taxes have a small negative impact on growth except for the tax on bio-accumulative emissions released in water (BIOWAT), which has a larger impact (an 8.1 percent decrease in GDP over 18 years with respect to what it would have been under BAU). The effects of these taxes on other aggregate measures of economic activity tend to be small as well, with the same exception of the tax on BIOWAT. Trade decreases by about 10 percent and investment decreases by 23 percent. Next we look at sectoral output effects. For the first four taxes (all three toxics, BIOAIR), fish and seafood output increase significantly (increases of 60 to 193 percent). For the same effluent taxes, mining activities decrease sharply (-17 to -60 percent). The tax on BIOWAT, which induces the largest decrease in aggregate output, has a negative effect on virtually all sectors, and it especially has a strong effect on iron, coal, and basic metals (-30 to -59 percent).

Trade contracts with the effluent taxes. At the sectoral levels, trade effects are mixed (some decreases, some increases) and moderate. Some exceptions arise: imports and exports of fish increase by over 100 percent for the taxes on toxic pollution; imports of wine and liquors increase by 120 percent with the tax on VOC. The same VOC tax has a strong negative impact on many pollution-intensive manufacturing exports (furniture, chemicals, petroleum refining, and rubber).

The simulations results indicate that the impact of the taxes on pollution abatement is diverse. Strong complementarities are observed in several subsets of the 13 effluent types, despite the clear possibility of substitution among pollution emissions implied by our model since we do not impose any fixed proportions between output and emissions. An increase in the tax on one effluent induces a decrease in another effluent level. All toxics are such a group, so are all bio-accumulative emissions, and NO_2, SO_2 and PART(PM-10). The larger subset of toxics and bio-accumulative emissions follows such a pattern. More intriguing is the presence, in the aggregate, of substitution possibilities among effluents. For example, SO_2 and NO_2 are substitutes for TSS and for bio-accumulative emissions in air and soil.

The tax rates implied by the targeted decrease in emissions are realistic: on average the pollution tax per unit of sectoral output is 4 percent or less for all 13 scenarios. The individual tax rates (per sector and by effluent) vary from zero to less than 15 percent for all 13 scenarios, except for the scenario targeting reduction in VOC. In the latter scenario the pollution tax rate on wine and liquors jumps to 52 percent, and the corresponding tax rate on furniture products is 37 percent. These high rates are caused by the fact that these two sectors account for most of the VOC pollution in production.

The decomposition of abatement into scale (aggregate output expansion), composition (composition of GDP), and technique (input substitution) effects reveals interesting results (see Copeland and Taylor for such an analytical decomposition). First, the composition effect seems overwhelming both in the abatement in production and consumption. The effect is more substantial in production than in consumption, that is, imports substitute for domestic output in pollution-intensive sectors. The technical effect in production is moderate, and the scale effect is marginal for most pollutants except for the case of the tax on BIOWAT (production scale effect of -8.1 percent). Surprisingly, a few simulations exhibit positive scale effects in production abatement (all toxics, BIOAIR, BIOSOL, and BOD). Since the scale effect is an aggregate output effect over all sectors, the latter result may be due to the expansion of activities that are not intensive in the pollutants being taxed. This expansion, weighted by prices, outweighs the decrease in output in polluting sectors. For example, the taxes on all three toxics decrease mining activities as well as metallic industries, but stimulate fisheries and seafood, and forestry and wood products.

This example shows the limitation of tackling environmental degradation by type of pollution effluent. Abatement of one effluent gives rise to an increase in resource-intensive activities such as forestry and may induce additional degradation and welfare losses if externalities are present in these sectors. This insight reinforces the finding that targeting one specific pollutant can have unintended and damaging consequences on emissions of “substitute” pollutants, and calls for an integrated approach to the design of environmental policies.

In addition, the decomposition of abatement sheds light on the substitutability between effluents. A variety of patterns emerges. Substitution between two effluent types occurs when all three effects are positive (for example, TSS response to tax on TOXWAT), or when two or less out of the three effects are positive and larger in magnitude than the remaining effect(s) (for example CO_2 response to BOD tax).

The impact of the effluent taxes on the concentration in Santiago is diverse and to some extent, follows the complementarity/substitution patterns observed for emissions. As shown in Table V.4a, all three toxic taxes provide significant decreases in lead (about 10 percent), but nothing else, except for a slight increase in CO concentration (1.1 percent). The three bio-accumulative pollution taxes decrease lead concentrations as well (by 10 to 20 percent). The tax on BIOWAT has negative and sometime large effects on other concentrations as well -remember it is the tax which has the largest negative scale effects among the effluent taxes. Air pollution taxes also produce similar concentration patterns. Emission taxes on either NO_2, SO_2, or PM-10 leads to a substantial decrease in the other two (averaging about 19 percent), and some decrease in CO (averaging about 5 percent). Taxes on CO and VOC also achieve substantial decreases in concentration in Santiago. The taxes on water pollution (BOD, TSS) have marginal impact on most of the concentrations.

As shown in Table 3, the health endpoints changes are striking for the taxes on SO_2, NO_2, and PM-10. Premature mortality due to PM-10, SO_2 and ozone decreases by more than 30 percent. With these three taxes, most endpoints show improvements with decreases of morbidity of about 30 percent for seven of the morbidity measures. There is a marginal deterioration of morbidity incidence linked to lead (about 1 percent). This result is the consequence of the slight increase in BIOAIR emissions induced by the taxes on SO_2 and NO_2 (around 4 percent).

Table 4 presents the health damages reduction induced by the environmental taxes. The tax on PM-10 induces a decrease in monetary damages equivalent to .82 percent of the BAU 2010 GDP; taxes on SO_2 and NO_2 reduce damages by an amount equivalent to .65 percent of BAU 2010 GDP. The latter taxes induce net gains as approximated by the loss of aggregate income plus the reduction in damages. These results show the importance of accounting for nonmarket benefits when considering the impact of environmental taxes. The estimated welfare gains are lower-bound estimates because the decreases in morbidity and mortality are only applied to Santiago’s population. As suggested by the Table some taxes such as the tax on VOC induce negligible net gains in welfare.

5.2 Trade Integration

We look at two types of trade integration leading to three scenarios: with the world (unilateral liberalization), and regional integration (NAFTA, and MERCOSUR). Unilateral liberalization induces the largest increase in GDP (+5.6 percent), followed by NAFTA (1.4 percent) and MERCOSUR (0.6 percent). These gains are small -they represent the relative gains over 18 years. These small changes originate in the outward-orientation Chile has been following; large gains from liberalization have already occurred. Nevertheless these reforms have more significant positive impacts on aggregate trade and aggregate gross investment.

Moving to sectoral output effects, the three trade reforms exhibit sharp contrast. The unilateral trade reform stimulates the output of fruit, forestry, iron, other mining, food processing, wood products, paper, and petroleum refining. Conversely, petroleum and gas production, chemicals, glass and other manufacturing contract with free trade. With NAFTA integration, fruit, agricultural services, other mining, food processing, wine and liquor, would expand significantly, whereas copper, iron, and paper would decrease. Hence, NAFTA integration departs significantly from free trade in terms of international specialization. MERCOSUR integration does not induce any strong effect, except for a major increase in transportation material and a decrease in fish and seafood.

The trade effects of these reforms are as follows. The unilateral reform induces major increases in virtually all sectoral imports and exports, except for imports of chemicals, glass, and other manufacturing. NAFTA integration has a smaller effect on trade than unilateral reform, except for noticeable increases in imports of agriculture and sugar, and smaller increases for livestock, forestry, fish, mining sectors, sugar, wood products, furniture, paper, and plastic; exports of fruits, mining (other than copper, coal, and iron), dairy, wine and liquor, furniture, and pottery.

Finally, the MERCOSUR integration induces increases in imports of agricultural products, iron, oils, sugar, tobacco, petroleum refining, and metals; imports of fish would decrease. On the export side, substantial reductions occur in exports of fish, iron, and seafood; but food processing, chemicals, plastics, and printing expand significantly.

The pollution implications of these trade reforms are next. Unilateral liberalization is pollution intensive, e.g., NO_2, SO_2, and PM-10 have an elasticity of 3.5 with respect to GDP increases induced by this unilateral reform. By contrast, MERCOSUR and NAFTA have elasticity values around 2.7 and 2.2 respectively, for the same effluents. NAFTA integration induces decreases in several pollutants (the three toxics, BIOAIR, BIOSOL, and BOD). MERCOSUR induces a decrease in TSS only. The trade diversion of NAFTA integration provides a significant environmental benefit in terms of mitigated emissions, relative to other two trade liberalization scenarios. This is a overlooked insight on trade diversion in presence of externalities. The decrease in effluents under the NAFTA scenario is achieved through strong composition effects in production, outweighing the scale expansion induced by NAFTA. By contrast, the unilateral trade liberalization induces higher intensities in SO_2, NO_2, and PART (PM-10) via strong technical effects towards pollution-intensive input combinations.

Still under free trade, we observe marginal increases for all toxics, BIOAIR, CO_2, VOC, and BOD; we have marginal decreases for TSS, and BIOSOL. Finally, we see substantial increases for PM-10, SO_2, and NO_2. These increases are observed after 18 years of expected growth and hence do not represent anything dramatic. By contrast, NAFTA membership induces decreases in pollution intensity of GDP or production. This difference between the two trade reforms is caused by the cheap energy import occurring under free trade but not under NAFTA.

For the health end-points in Santiago, the unilateral trade liberalization scenario has negative consequences for both mortality and almost all measures of morbidity. Premature mortality due to PM-10, ozone, and SO_2 increases by 25 percent and premature death in males of age 40-59 due to lead increases by 9.2 percent, as shown in Table 3. Morbidity increases range from 9 percent for cases of hypertension and non-fatal heart attacks to about 26 percent for chest discomfort episodes and respiratory symptoms in children. NAFTA and MERCOSUR induce marginal increases in the health end-points. Although NAFTA decreases several types of emissions, these decreases do not translate into major gains for urban health because these improvements are not relevant for air pollution in Santiago, except for a small improvement in lead concentration. The damages associated with the health incidences are substantial for the unilateral trade liberalization. As suggested by Table 4, the damages represent 13 percent of the aggregate income gains induced by trade liberalization (damages as percent of gains in GDP). By contrast the damages under the NAFTA scenario are moderate due to the small deterioration of the average health status in Santiago.

5.3 Trade Integration with Environmental Protection

In this last set of reforms, we first combine NAFTA reforms and effluent taxes on a subset of pollutants (air pollutants). Then, we consider the unilateral trade liberalization coordinated with effluent tax on one pollutant at the time. The effluent taxes are designed as in the first set of scenarios on environmental reforms (incremental and leading to a 25-percent decrease in emissions of the taxed effluent). The tax rates corresponding to these reforms are slightly higher than in the environmental reforms alone. The average tax rates on pollution, expressed in percent of the producer price per unit of output, do not exceed 5.8 percent. A few individual rates increase sharply . For instance, The tax on TOXWAT emitted by nonmetallic minerals increases to 23.6 percent. As expected, the tax rates on VOC for wine and liquor and for furniture products increase further to 73 and 53 percent, respectively. These increases in tax rates originate in the output and pollution expansion induced by trade liberalization. The pollution expansion requires higher tax rates to be abated back to the level corresponding to a 25 percent decrease with respect to the BAU level.

The aggregate effect of the combined reforms (NAFTA *cum* effluent tax) is small in general, but differs according to the pollutant considered. For example, the effluent tax on CO_2 has practically no effect on aggregate measures, whereas, the tax on VOC has a negative impact on production, consumption and real income. The sectoral variation is more insightful. The iron ore, petro-gas and petroleum refining sectors decrease considerably for several of the effluent taxes. The VOC tax drastically reduces the output of wine and liquors, and of chemicals. Finally, the tax on BIOAIR (lead) induces an expansion of fish, seafood and fruit, but a strong contraction of copper.

The net trade effects of the combined NAFTA and environmental policy reform are next. Specifically, imports of fruits, iron ore, coal, other mining, nonmetallic minerals, electricity and transportation increase for most effluent taxes; conversely, imports of petro-gas and petroleum refining decrease. Exports of fish, iron ore, seafood, food processing, feeds, paper, petroleum refining, glass, nonmetallic minerals, and transportation decrease.

The pollution abatement figures, including the multiplier effects of the tax on pollutants that are not directly targeted by the tax, are surprisingly similar to the abatement figures for the reforms limited to environmental reforms alone. The abatement on the targeted emission is of course exactly similar by design, but the indirect abatement of the other pollutants does not have to be because relative prices are different under the two scenarios. The result is surprising because changing border prices affects specialization and hence pollution. This result is due to the fact that NAFTA integration has a mitigated impact on the Chilean environment.

The impact of coordinated reforms -free trade *cum* environmental taxes- appears almost additive on aggregate output, trade and consumption: the aggregate effect of the coordinated approach is the sum of aggregate effect of the two individual reforms. This is a recurrent result in this type of simulation exercise (Lee and Roland-Holst; Beghin, Roland-Holst and van der Mensbrugghe (1995) and (1997B)). However, the disaggregated output and trade figures reveal more interesting, if not surprising, and diverse patterns. For example, iron ore output increases by 51 percent with trade liberalization and decreases by 14 percent with the tax on SO_2. Nonetheless, the combined reform (free trade + SO_2 tax) induces an marginal increase in output of 1.4 percent! This diversity of patterns comes from the difference in relative cost of abatement by increasing imports (composition) and by changing the input mix (technical effect) under different policy regimes. Output of fish, seafood, and wood products increases considerably for several of the free trade *cum* effluent tax scenarios.

Aggregate trade expands less under the coordinated reforms than under the simple unilateral trade liberalization, although some sectoral import induced by the latter reform, grow even more under the coordinated scenario. For instance, imports of fish are larger under the combined scenario than under the free trade scenario. These exacerbated surges are explained by the almost additive effects of the two policies: free trade and environmental protection imply the same international specialization. For example, fish imports increases significantly with the environmental reforms and with free trade. However, the effect under coordinated policies is lower than the sum of the individual one.

The inventory of emissions tends to duplicate the patterns reached under the single effluent tax reform since we target the amount of pollution in a similar fashion (-25 percent for each effluent type). Nevertheless, the substitution between bio-accumulative and toxic pollutants as a group and the air pollutants (SO_2, NO_2, VOC, PM-10, and CO_2) as another group is amplified by free trade. This increased substitution is caused by a selective increase in pollution dictated by the change in relative prices of pollutants when only one type of pollutant is taxed. For instance, the copper and other-mining sectors decrease their activity for the combined scenario targeting toxic and bio-accumulative emissions, but increase their activities under the four coordinated scenarios targeting SO_2, NO_2, PM-10 and CO_2. VOC emissions increase under most scenarios except the one which taxes VOC emissions.

Finally, as indicated by Table 3, the urban health impact of the coordinated reforms reflects these stronger substitutions between broad groups of pollutants. Mortality due to air pollution increases dramatically under the combined scenarios involving bio-accumulative and toxic pollution, because the emissions of PM-10, SO_2, and NO_2 are stimulated. Similarly, the morbidity induced by SO_2, NO_2, PM-10 and CO increases under the same combined scenarios. The VOCs-ozone increases have a negative effect on many morbidity measures: increase in restricted activity days, in the number of asthma attacks, respiratory symptoms, in minor restricted activity days, and in eye irritation cases. As shown in the last part of Table 4, damages reductions under coordinated reforms are less substantial than under the environmental tax alone, because of the substitution forces at work among pollutant types. For example, damages caused by lead pollution are substantial in the coordinated scenario involving a tax on PM-10. Nevertheless, the net welfare gains of combined reforms are much higher than for trade liberalization alone. For example, the tax on PM-10 combined to free trade induces net welfare gains which are 14 percent higher than the net gains under free trade alone.

6 Conclusions

This paper seeks to elucidate linkages between trade, environment, and public health status in an outward-oriented economy. From our results, it is apparent that such linkages are quite complex, and policy makers relying on intuition alone are unlikely to achieve anything close to optimality. Policies in all three areas are clearly interdependent, and better coordination could reduce the social and economic costs of economic growth and environmental mitigation. More detailed empirical work is needed, however, to support such policies.

Trade liberalization scenarios offer different outcomes in terms of growth, international division of labor and environmental consequences. Integration into NAFTA is relatively benign to the environment and has the smallest pollution elasticity with respect to the trade-induced growth (the percentage change in pollution with respect to the percentage change in GDP). Unilateral trade liberalization, with no abatement policy, induces higher growth and patterns of specialization more adverse towards the environment, leading to detrimental impacts on public health in Santiago and considerable monetary damages associated with the negative health impact. MERCOSUR simulations do not indicate substantial changes in income, pollution or public health, except for increased emissions of bio-accumulative pollutants, and small increases in mortality and morbidity linked to lead pollution in Santiago.

Considering effluent taxes alone, the abatement of three pollutants, SO_2, NO_2, and PM-10 achieves the largest decrease in both mortality and morbidity in Santiago. The health damage reduction exceeds the foregone aggregate income and corresponds to a net welfare gain to the Chilean economy.

Coordinated scenarios are well-grounded in economic theory and represent the best of both worlds (efficiency gains from trade, and protected environment); they are characterized by economic expansion and decreases in the emissions of the targeted pollutant as well as its polluting “complements”. Nevertheless, emissions of untaxed substitute pollutants increase considerably. These strong substitutions have a negative impact on urban health, with notable increases in mortality and morbidity when toxic and bio-accumulative pollutants are the targets. Further, several natural-resource based sectors expand as well, hence increasing the dimensionality of policy coordination (trade policy, effluent taxes, natural resource management). This is a result specific to our investigation of Chile. By contrast, our analysis of trade and environment linkages in Mexico suggests mostly complementarity between effluent types (Beghin et al. (1995) and (1997b)).

The observed substitutability among pollutant types and its implications for urban health raises two additional coordination and targeting issues. The first one is the coordination of environmental programs targeting subgroups of pollutants (e.g., toxic, bio-accumulative, air criteria pollutants). Given the substantial substitutability between these groups, an integrated approach to environmental reform encompassing all major groups of pollutants appears appropriate to avoid unintended environmental degradation or negative health consequence.

The other issue is the hopeful observation that strong complementarities exist within some groups of pollutants and that a policy targeting any pollutant within a group would achieve substantial abatement in most emission types included in the group. This finding is common to most of our case studies and emerges as an empirical regularity in these linkages.

Another regularity shared by this study and the other case studies using the same methodology is the relatively low cost of pollution abatement in terms of foregone aggregate income. In this specific case of Chile and Santiago, we establish this result in terms of welfare. The monetary damages equivalent to the health impact of air pollution are greatly reduced by environmental taxes, especially by the tax on PM-10, NO_2, and SO_2 , such that the these welfare gains exceed the loss of GDP induced by the taxes. A net welfare gain emerges. This statement should be qualified because the resource reallocation implied by the effluent taxes is substantial on a sectoral basis and we do abstract from explicit adjustment cost.

The observed substitutability among pollutant types raises two additional coordination and targeting issues. The first one is the coordination of environmental programs targeting subgroups of pollutants (e.g., toxic, bio-accumulative, air criteria pollutants). Given the substantial substitutability between these groups, an integrated approach to environmental reform encompassing all major groups of pollutants appears appropriate to avoid unintended environmental degradation.

The other interesting point is the hopeful observation that strong complementarities also exist within some groups of pollutants and that a policy targeting any pollutant within a group would achieve substantial abatement in most emission types included in that group.

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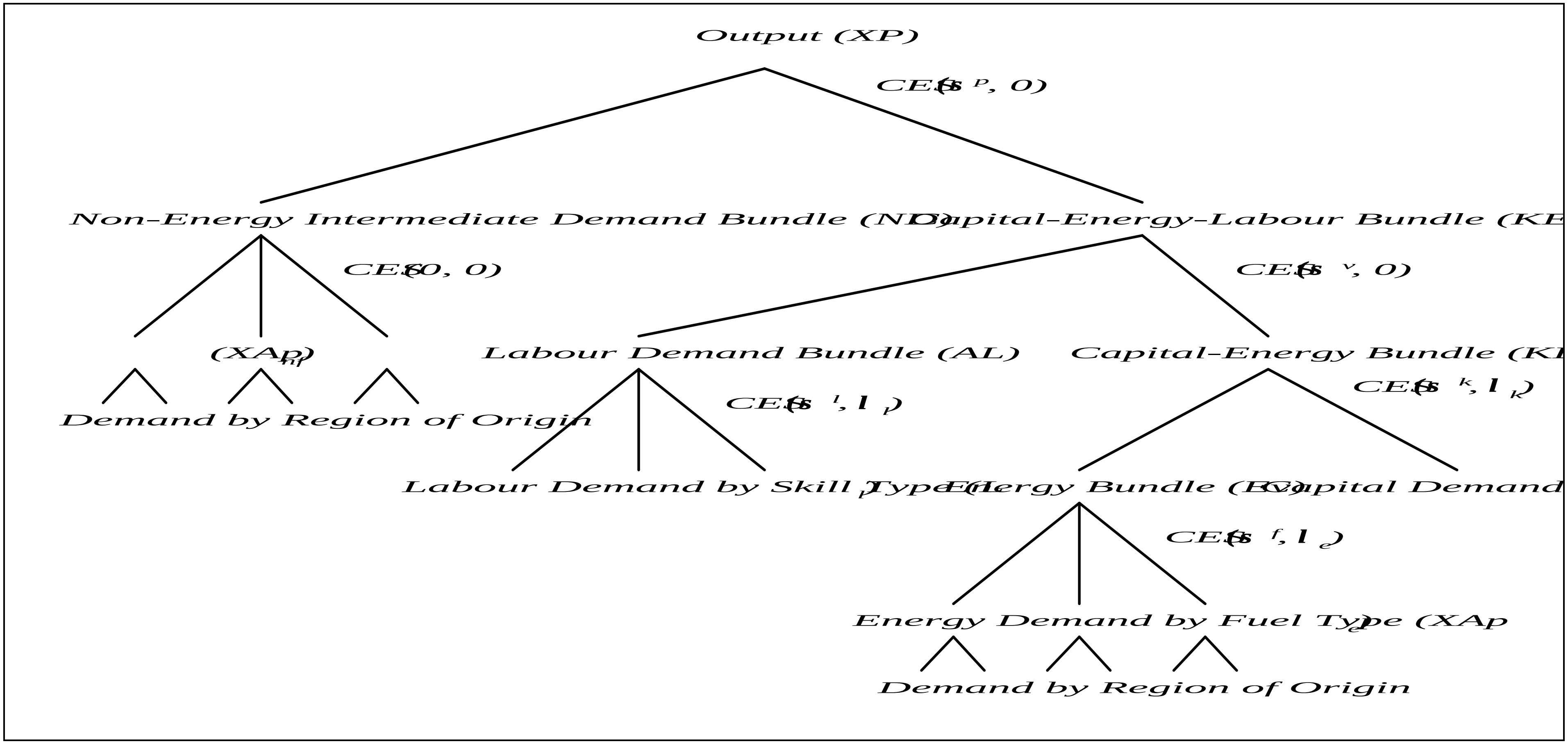
Figure 1: **Production Nesting**



Notes:

1. Each nest represents a different CES bundle. The first argument in the CES function represents the substitution of elasticity. The elasticity may take the value zero. Because of the putty/semi-putty specification, the nesting is replicated for each type of capital, i.e. *old* and *new*. The values of the substitution elasticity will generally differ depending on the capital vintage, with typically lower elasticities for *old* capital. The second argument in the CES function is an efficiency factor. In the case of the *KE* bundle, it is only applied on the demand for capital. In the case of the decomposition of labor and energy, it is applied to all components.
2. Intermediate demand, both energy and non-energy, is further decomposed by region of origin according to the *Armington* specification. However, the *Armington* function is specified at the border and is not industry specific.
3. The decomposition of the intermediate demand bundle, the labor bundle, and the energy bundle will be specific to the level of aggregation of the model. The diagram represents only schematically the decomposition and is not meant to imply that there are three components in the CES aggregation.

Table 1 Impact of Policy Reform on Aggregate Variables

	Environmental Reform: Aggregate Abatement of 25% by Type of Effluent Emission												
Aggregate Variables	**toxair**	**Toxwat**	**Toxsol**	**bioair**	**Biowat**	**biosol**	**so2**	**no2**	**co**	**voc**	**part**	**bod**	**tss**
Real GDP	-0.7	-0.8	-0.7	-0.3	-8.1	-0.3	-0.2	-0.2	-0.1	-0.4	-0.3	-0.7	0.0
Production	0.4	0.3	0.3	0.3	-8.1	0.4	-2.4	-2.4	-0.8	-3.0	-2.6	0.3	-0.1
Consumption	-0.4	-0.5	-0.4	0.0	-1.6	0.0	-1.3	-1.3	-0.2	-1.8	-1.3	-0.4	0.0
Investment	-2.1	-2.6	-2.2	-0.8	-23.2	-0.7	-1.3	-1.3	-0.4	-2.0	-1.5	-2.3	-0.1
Exports	-1.6	-1.9	-1.7	-1.0	-10.2	-0.8	-3.1	-3.1	-0.6	-2.1	-3.2	-1.7	0.0
Imports	-1.2	-1.4	-1.3	-0.7	-9.6	-0.5	-3.0	-3.0	-0.5	-1.7	-3.1	-1.3	0.0
Labor Supply	-0.2	-0.3	-0.2	-0.1	-3.1	-0.1	0.2	0.2	0.0	-0.1	0.2	-0.2	0.0
Capital Supply	-0.9	-1.1	-0.9	-0.4	-10.4	-0.3	-0.6	-0.6	-0.2	-0.7	-0.7	-1.0	0.0
Real Income	-0.3	-0.5	-0.4	0.0	-1.3	0.0	-1.2	-1.2	-0.1	-2.5	-1.2	-0.4	0.0
Absorption	-0.8	-1.0	-0.8	-0.2	-7.1	-0.2	-1.2	-1.2	-0.2	-1.7	-1.2	-0.8	0.0

	Trade Policy Reform[a]			Combined NAFTA and Environmental Policy Reform[b]				
Aggregate Variables	**lib2**	**Nafta2**	**Mercosu**	**Bioairn**	**so2n**	**No2n**	**con**	**vocn**	**partn**
Real GDP	5.6	1.4	0.6	1.2	1.2	1.2	1.4	0.9	1.1
Production	7.3	1.6	0.6	1.8	-1.1	-1.1	0.7	-1.8	-1.4
Consumption	9.2	2.1	0.9	2.1	0.6	0.6	1.8	-0.1	0.6
Investment	17.7	4.3	1.8	3.5	2.7	2.7	3.7	1.9	2.4
Exports	18.0	3.6	2.7	2.7	0.1	0.1	2.9	1.2	-0.1
Imports	29.1	6.0	3.9	5.3	2.4	2.4	5.3	3.9	2.3
Labor Supply	2.0	0.8	0.2	0.7	1.0	1.0	0.8	0.6	1.0
Capital Supply	7.2	1.7	0.7	1.4	1.1	1.1	1.5	0.9	0.9
Real Income	8.6	2.0	0.8	2.1	0.6	0.6	1.9	-0.9	0.6
Absorption	10.5	2.4	1.0	2.3	1.1	1.1	2.2	0.5	1.0

[a]Reflects unilateral trade liberalization, NAFTA integration and MERCOSUR integration by 2010 with no explicit environmental policy reforms.

[b]Reflects combined policy reforms of NAFTA integration and aggregate abatement of 25% by type of effluent emission.

Table 1 (continued)

Unilateral Trade with Aggregate Abatement of 25% by Type of Effluent Emission

Aggregate Variables	toxairl	Toxwatl	toxsoll	bioairl	biowatl	biosoll	so2l	no2l	col	voc	partl	bodl	tssl
Real GDP	4.7	4.4	4.7	5.3	-7.4	5.4	5.2	5.2	5.5	4.9	5.0	4.7	5.6
Production	7.8	7.5	7.8	7.9	-5.9	7.9	2.9	2.9	5.5	2.4	2.5	7.8	7.1
Consumption	8.7	8.4	8.7	9.1	6.3	9.1	6.7	6.7	8.6	6.0	6.7	8.6	9.2
Investment	14.4	13.3	14.4	16.9	-21.9	17.1	14.9	14.9	16.6	13.9	14.5	14.3	17.6
Exports	16.4	15.9	16.4	17.0	0.2	17.5	11.7	11.8	16.2	13.5	11.6	16.3	17.9
Imports	27.9	27.4	27.9	28.3	10.5	28.9	22.2	22.3	27.3	24.7	22.2	27.9	29.1
Labor Supply	1.7	1.7	1.7	1.8	-2.9	1.9	2.4	2.4	2.2	1.9	2.3	1.7	2.0
Capital Supply	6.1	5.7	6.0	6.9	-9.6	6.9	6.2	6.2	6.9	6.0	6.0	6.0	7.2
Real Income	8.2	7.9	8.1	8.6	6.1	8.6	6.2	6.3	8.2	4.4	6.3	8.1	8.6
Absorption	9.3	8.8	9.3	10.3	-1.8	10.3	8.2	8.2	9.9	7.5	8.1	9.3	10.5

7.1.1 Table 2: Impact of Policy Reforms on National Effluent Emissions

	Aggregate Abatement of 25% by Type of Effluent Emission												
Effluent Emissions	**toxair**	**toxwat**	**toxsol**	**Bioair**	**Biowat**	**biosol**	**So2**	**no2**	**co**	**voc**	**part**	**bod**	**tss**
TOXAIR	-25.0	-27.4	-25.0	-15.7	-11.9	-14.5	0.9	0.7	0.9	-0.1	0.8	-25.2	0.1
TOXWAT	-22.7	-25.0	-22.7	-13.8	-11.5	-12.8	-0.5	-0.6	0.7	-1.2	-0.5	-22.9	0.1
TOXSOL	-25.0	-27.4	-25.0	-15.4	-12.2	-14.3	1.1	1.0	1.0	0.0	1.1	-25.2	0.1
BIOAIR	-29.5	-31.5	-29.1	-25.0	-18.7	-19.8	4.4	4.1	-4.5	2.0	0.4	-29.1	-3.0
BIOWAT	-2.0	-2.3	-2.0	-1.7	-25.0	-0.7	-0.3	-0.2	-4.1	-1.5	-3.0	-2.1	-2.0
BIOSOL	-37.3	-39.9	-36.8	-27.3	-13.7	-25.0	4.2	3.8	1.6	3.7	4.1	-36.9	0.0
SO2	-0.6	-1.4	-0.5	0.4	-5.2	0.2	-25.0	-25.0	-4.1	-10.2	-25.2	-0.5	0.5
NO2	-0.6	-1.4	-0.5	0.4	-5.2	0.2	-25.0	-25.0	-4.1	-10.1	-25.3	-0.6	0.5
CO_2	0.4	0.3	0.6	-5.1	-29.8	0.6	-8.0	-7.9	-25.0	-4.7	-23.6	0.6	-11.9
VOC	-0.9	-1.5	-0.9	0.1	-4.0	0.1	-3.5	-3.4	-0.6	-25.0	-3.4	-0.9	0.0
PART	-0.6	-1.3	-0.5	-0.2	-7.8	0.2	-23.1	-23.1	-6.2	-9.3	-25.0	-0.5	-0.8
BOD	-24.7	-27.2	-24.8	-15.2	-12.2	-14.0	1.1	0.9	1.0	-0.1	1.1	-25.0	0.1
TSS	0.6	1.2	0.9	-11.7	-55.5	0.2	9.9	10.0	-47.0	0.8	-21.9	0.9	-25.0

	Trade Policy Reform[a]			Combined NAFTA and Environmental Policy Reform[b]				
Effluent Emissions	**lib2**	**Nafta2**	**Mercosur**	**bioairn**	**so2n**	**no2n**	**con**	**vocn**	**partn**
TOXAIR	8.6	-1.0	3.5	-13.9	-0.3	-0.4	-0.2	-1.4	-0.3
TOXWAT	9.5	-0.4	3.3	-11.8	-1.2	-1.3	0.1	-2.1	-1.3
TOXSOL	8.6	-0.8	3.5	-13.5	0.2	0.0	0.1	-1.1	0.1
BIOAIR	8.4	-3.6	8.1	-25.0	1.2	0.9	-8.6	-1.5	-3.2
BIOWAT	14.8	3.6	1.4	1.9	3.2	3.2	-0.9	1.7	0.2
BIOSOL	4.0	-4.8	4.8	-27.7	-0.4	-0.7	-3.4	-0.8	-0.5
SO2	19.9	3.1	1.6	3.4	-25.0	-25.0	-1.8	-8.4	-25.2
NO2	19.8	3.2	1.6	3.4	-25.0	-25.0	-1.8	-8.3	-25.2
CO_2	11.8	2.2	0.3	-2.8	-6.7	-6.7	-25.0	-3.2	-24.0
VOC	13.2	3.6	1.2	3.7	-0.4	-0.4	2.9	-25.0	-0.4
PART	18.9	3.1	1.5	2.8	-23.0	-23.0	-4.2	-7.5	-25.0
BOD	8.8	-0.8	3.5	-13.3	0.1	0.0	0.1	-1.1	0.1
TSS	2.8	1.4	-1.2	-10.0	12.6	12.6	-49.3	2.2	-22.8

Table 2 (continued)

	Unilateral Trade with Aggregate Abatement of 25% by Type of Effluent Emission												
	toxairl	toxwatl	toxsoll	Bioairl	biowatl	Biosoll	so2l	no2l	col	voc	partl	bodl	tssl
National Effluent Emissions													
TOXAIR	-25.0	-28.6	-24.9	-10.4	-9.4	-7.9	12.0	11.6	12.3	10.2	11.9	-25.2	8.8
TOXWAT	-21.3	-25.0	-21.2	-7.2	-8.4	-5.0	10.1	9.8	12.1	8.9	10.1	-21.6	9.7
TOXSOL	-25.1	-28.9	-25.0	-10.0	-9.9	-7.6	12.4	12.0	12.4	10.3	12.4	-25.4	8.9
BIOAIR	-28.5	-30.2	-27.9	-25.0	-15.8	-13.8	18.9	18.3	6.3	12.0	13.1	-27.9	5.2
BIOWAT	11.7	10.6	11.7	13.2	-25.0	14.3	13.8	13.9	8.9	11.8	9.8	11.6	12.5
BIOSOL	-44.0	-46.3	-43.4	-29.8	-13.5	-25.0	15.4	14.6	11.2	13.7	15.3	-43.5	4.3
SO2	18.4	16.2	18.7	20.7	8.9	20.3	-25.0	-24.9	7.2	0.9	-24.9	18.7	20.5
NO2	18.3	16.2	18.6	20.5	9.0	20.2	-25.1	-25.0	7.2	1.1	-25.0	18.6	20.4
CO_2	11.5	10.7	11.9	7.3	-26.3	12.9	-3.3	-3.2	-25.0	2.8	-26.0	11.9	-1.4
VOC	11.4	10.0	11.5	13.3	5.9	13.4	6.4	6.5	11.4	-25.0	6.7	11.4	13.2
PART	17.5	15.5	17.8	19.0	5.1	19.3	-22.7	-22.6	3.8	1.6	-25.0	17.7	18.1
BOD	-24.7	-28.5	-24.6	-9.5	-9.9	-7.2	12.3	12.0	12.5	10.3	12.4	-25.0	9.0
TSS	2.7	3.5	3.2	-8.6	-63.4	3.5	19.2	19.3	-59.2	4.3	-27.4	3.3	-25.0

Table 3: Impact of Environmental Policy Reform on Health Endpoints for Santiago

	Aggregate Abatement of 25% by Type of Effluent Emission												
Health Endpoints	**toxair**	**toxwat**	**toxsol**	**bioair**	**biowat**	**biosol**	**so2**	**no2**	**co**	**voc**	**part**	**bod**	**tss**
Premature Mortality/Year	0.5	-0.4	0.6	0.9	-10.3	1.1	-30.3	-30.3	-7.7	-13.0	-32.4	0.6	-0.7
Premature Mortality of males age 40-59/Year	-12.6	-13.5	-12.2	-15.8	-24.8	-8.9	1.7	1.6	-10.0	-4.8	-4.8	-12.2	-5.0
RHA/Year	0.3	-0.4	0.4	0.7	-7.7	0.9	-19.5	-19.4	-5.1	-15.2	-20.9	0.4	-0.5
ERV/Year	0.5	-0.4	0.7	0.5	-11.6	1.1	-29.3	-29.2	-8.7	-12.6	-32.1	0.6	-1.3
RAD/Year	0.5	-0.4	0.7	0.5	-11.6	1.1	-29.2	-29.2	-8.7	-12.6	-32.1	0.6	-1.3
LRI/Year (Children < age 17)	0.5	-0.4	0.7	0.5	-11.6	1.1	-29.2	-29.2	-8.7	-12.6	-32.1	0.6	-1.3
Asthma Attacks/Year (Asthmatics)	0.3	-0.3	0.3	0.7	-5.7	0.8	-14.4	-14.4	-3.3	-16.5	-15.1	0.3	-0.1
Respiratory Symptoms/Year	0.4	-0.4	0.5	0.6	-9.1	1.0	-23.0	-22.9	-6.4	-14.3	-24.9	0.5	-0.8
Chronic Bronchitis/Year	0.5	-0.4	0.7	0.5	-11.6	1.1	-29.2	-29.2	-8.7	-12.6	-32.1	0.6	-1.3
MRAD/Year	0.2	-0.3	0.2	0.8	-4.0	0.7	-10.0	-9.9	-1.6	-17.7	-10.0	0.2	0.2
Respiratory Symptoms/Year (Children)	0.5	-0.6	0.6	1.6	-7.4	1.2	-33.2	-33.1	-5.3	-14.2	-33.4	0.6	0.8
Chest Discomfort Episodes/Year	0.5	-0.6	0.6	1.6	-7.3	1.2	-33.1	-33.0	-5.3	-14.2	-33.3	0.6	0.8
Respiratory Symptoms/Year (Adults)	0.4	-0.6	0.6	1.5	-7.1	1.1	-32.6	-32.5	-5.2	-13.8	-32.8	0.5	0.8
Eye Irritations/Year (Adults)	0.2	-0.3	0.2	0.8	-4.0	0.7	-10.0	-9.9	-1.6	-17.7	-10.0	0.2	0.2
Headaches/Year	1.8	1.7	2.0	-8.0	-52.0	1.5	-8.8	-8.7	-42.9	-6.8	-35.4	2.0	-20.4
IQ decrements	-12.6	-13.5	-12.2	-15.8	-24.8	-8.9	1.7	1.6	-10.0	-4.8	-4.8	-12.2	-5.0
Cases of Hypertension/1 million males age >20	-12.6	-13.5	-12.2	-15.8	-24.8	-8.9	1.7	1.6	-10.0	-4.8	-4.8	-12.2	-5.0
Non-fatal Heart Attacks/1 million males age 40-59	-12.6	-13.5	-12.2	-15.8	-24.8	-8.9	1.7	1.6	-10.0	-4.8	-4.8	-12.2	-5.0

Note: All figures are percentage changes with respect to base trends in 2010.

KEY:
RHA = respiratory hospital admissions
ERV = emergency room visits
RAD = restricted activity days
LRI = lower respiratory illness
MRAD = minor restricted activity days
pphm = parts per hundred million
µg/m3 = micrograms per cubic meter

Table 3 (continued): Impact of Trade Reform and Combined NAFTA and Environmental Policy Reform on Health Endpoints for Santiago

	*Trade Policy Reform**			*Combined NAFTA and Environmental Policy Reform***					
Health Endpoints	**lib2**	**Nafta2**	**Mercosur**	**bioairn**	**so2n**	**no2n**	**con**	**vocn**	**partn**
Premature Mortality/Year	24.8	3.2	2.0	3.7	-30.6	-30.6	-5.7	-11.4	-32.9
Premature Mortality of males age 40-59/Year	9.2	-0.6	8.4	-15.1	1.3	1.2	-11.6	-5.9	-5.9
RHA/Year	18.7	3.0	1.5	3.4	-18.8	-18.7	-3.0	-14.2	-20.4
ERV/Year	24.2	3.2	1.9	3.4	-29.5	-29.4	-6.9	-10.9	-32.6
RAD/Year	24.2	3.2	1.9	3.4	-29.4	-29.4	-6.8	-10.9	-32.6
LRI/Year (Children < age 17)	24.2	3.2	1.9	3.4	-29.4	-29.4	-6.8	-10.9	-32.6
Asthma Attacks/Year (Asthmatics)	15.9	2.9	1.3	3.4	-13.3	-13.3	-1.0	-16.0	-14.1
Respiratory Symptoms/Year	20.7	3.1	1.6	3.4	-22.6	-22.6	-4.4	-13.0	-24.8
Chronic Bronchitis/Year	24.2	3.2	1.9	3.4	-29.4	-29.4	-6.8	-10.9	-32.6
MRAD/Year	13.5	2.7	1.1	3.4	-8.4	-8.4	0.8	-17.5	-8.5
Respiratory Symptoms/Year (Children)	26.4	3.3	2.2	4.5	-33.8	-33.7	-3.1	-12.6	-34.0
Chest Discomfort Episodes/Year	26.3	3.3	2.2	4.5	-33.6	-33.6	-3.1	-12.6	-33.8
Respiratory Symptoms/Year (Adults)	25.8	3.3	2.1	4.4	-33.1	-33.1	-3.0	-12.2	-33.3
Eye Irritations/Year (Adults)	13.4	2.7	1.1	3.4	-8.4	-8.4	0.8	-17.5	-8.5
Headaches/Year	17.6	3.0	0.2	-5.1	-6.6	-6.5	-43.9	-4.6	-36.3
IQ decrements	9.2	-0.6	8.4	-15.1	1.3	1.2	-11.6	-5.9	-5.9
Cases of Hypertension/1 million males age >20	9.2	-0.6	8.4	-15.1	1.3	1.2	-11.6	-5.9	-5.9
Non-fatal Heart Attacks/1 million males age 40-59	9.2	-0.6	8.4	-15.1	1.3	1.2	-11.6	-5.9	-5.9

*Reflects unilateral trade liberalization, NAFTA integration and MERCOSUR integration by 2010
with no explicit environmental policy reforms.

**Reflects combined policy reforms of NAFTA integration and aggregate abatement of 25% by type of effluent emission.

Note: All figures are percentage changes with respect to base trends in 2010.

KEY: RHA = respiratory hospital admissions
ERV = emergency room visits
RAD = restricted activity days
LRI = lower respiratory illness
MRAD = minor restricted activity days
pphm = parts per hundred million
µg/m3 = micrograms per cubic meter

Table 3 (continued): Impact of Coordinated Trade and Environmental Policy Reforms on Health Endpoints for Santiago

Unilateral Trade liberalization with Aggregate Abatement of 25% by Type of Effluent

Health Endpoints	toxairl	toxwatl	toxsoll	bioairl	biowatl	biosoll	so2l	no2l	col	voc	partl	l	
Premature Mortality/Year	25.2	22.3	25.6	26.9	6.0	26.9	-29.8	-29.7	5.1	0.5	-32.4		
Premature Mortality of males age 40-59/Year	-5.9	-7.1	-5.2	-14.3	-24.5	0.9	12.4	12.2	-4.7	-1.4	2.5		
RHA/Year	18.9	16.8	19.2	20.2	4.9	20.3	-16.5	-16.4	5.8	-7.2	-18.3		
ERV/Year	24.6	21.9	25.0	25.9	4.0	26.3	-28.5	-28.4	3.4	0.8	-32.3		
RAD/Year	24.6	21.9	25.0	25.9	4.0	26.2	-28.5	-28.3	3.4	0.8	-32.3		
LRI/Year (Children < age 17)	24.6	21.9	25.0	25.9	4.0	26.2	-28.5	-28.3	3.4	0.8	-32.3		
Asthma Attacks/Year (Asthmatics)	15.9	14.2	16.2	17.3	5.3	17.2	-10.4	-10.3	7.1	-11.3	-11.1		
Respiratory Symptoms/Year	20.9	18.6	21.3	22.3	4.6	22.5	-20.8	-20.7	5.0	-4.3	-23.3		
Chronic Bronchitis/Year	24.6	21.9	25.0	25.9	4.0	26.2	-28.5	-28.3	3.4	0.8	-32.3		
MRAD/Year	13.3	11.9	13.5	14.7	5.7	14.5	-4.9	-4.8	8.3	-15.0	-4.7		
Respiratory Symptoms/Year (Children)	26.8	23.7	27.2	29.4	10.8	28.7	-33.3	-33.1	9.3	-0.2	-33.1		
Chest Discomfort Episodes/Year	26.7	23.6	27.1	29.3	10.8	28.5	-33.2	-33.0	9.3	-0.2	-33.0		
Respiratory Symptoms/Year (Adults)	26.1	23.1	26.5	28.5	10.7	27.8	-32.8	-32.7	9.0	-0.1	26.4	-32.6	26.7
Eye Irritations/Year (Adults)	13.3	11.9	13.5	14.6	5.7	14.5	-4.9	-4.8	8.2	-15.0	-4.7	13.4	13.7
Headaches/Year	19.0	17.9	19.6	11.0	-49.7	20.4	0.4	0.7	-46.0	4.7	-39.0	19.6	-5.3
IQ decrements	-5.9	-7.1	-5.2	-14.3	-24.5	0.9	12.4	12.2	-4.7	-1.4	2.5	-5.1	3.5
Cases of Hypertension/1 million males age >20	-5.9	-7.1	-5.2	-14.3	-24.5	0.9	12.4	12.2	-4.7	-1.4	2.5	-5.1	3.5
Non-fatal Heart Attacks/1 million males age 40-59	-5.9	-7.1	-5.2	-14.3	-24.5	0.9	12.4	12.2	-4.7	-1.4	2.5	-5.1	3.5

Note: All figures are percentage changes with respect to base trends in 2010.

KEY: RHA = respiratory hospital admissions
ERV = emergency room visits
RAD = restricted activity days
LRI = lower respiratory illness
MRAD = minor restricted activity days
pphm = parts per hundred million
µg/m3 = micrograms per cubic meter

Table 4: Impact of Environmental Policy Reform on Mortality and Morbidity Health Damages for Santiago (in millions 1992 PPP$)

	Aggregate Abatement of 25% by Type of Effluent												
Health	**toxair**	**toxwat**	**toxsol**	**bioair**	**biowat**	**biosol**	**so2**	**no2**	**co**	**voc**	**part**	**bod**	**tss**
Mortality	(16)	(44)	(13)	(13)	(348)	9	(844)	(844)	(240)	(375)	(918)	(13)	(32)
Morbidity	(422)	(467)	(406)	(530)	(1,028)	(286)	(393)	(396)	(474)	(397)	(658)	(407)	(190)
Total	(438)	(511)	(418)	(543)	(1,376)	(276)	(1,237)	(1,240)	(714)	(773)	(1,576)	(419)	(222)
Total (% Chile BAU	(0.23)	(0.27)	(0.22)	(0.28)	(0.72)	(0.14)	(0.65)	(0.65)	(0.37)	(0.40)	(0.82)	(0.22)	(0.12)

Note: All mortality and morbidity figures are valued at a reference level of GDP/capita income in 2010 under BAU (measured in 1992 PPP$).

Note: values represent welfare gains from policy reform relative to BAU in 2010.

Table 4 (continued): Impact of Trade Reform and Combined NAFTA and Environmental Policy Reform on Morbidity Health Damages for Santiago (in millions 1992 PPP$)

	Trade Policy Reform*			Combined NAFTA and Environmental Policy Reform**					
Health Damages	**lib2**	**Nafta2**	**Mercosur**	**bioairn**	**so2n**	**no2n**	**con**	**vocn**	**partn**
Mortality	716	88	76	67	(853)	(853)	(187)	(333)	(935)
Morbidity	703	34	317	(457)	(405)	(408)	(494)	(409)	(699)
Total	1,419	122	393	(389)	(1,258)	(1,262)	(682)	(743)	(1,634)
Total (% Chile BAU GDP)	0.74	0.06	0.21	(0.20)	(0.66)	(0.66)	(0.36)	(0.39)	(0.85)

*Reflects unilateral trade liberalization, NAFTA integration and MERCOSUR integration by 2010 with no explicit environmental policy reforms.

**Reflects combined policy reforms of NAFTA integration and aggregate abatement of 25% by type of effluent emission.

Note: All mortality and morbidity figures are valued at a reference level of GDP/capita in 2010 under BAU (measured in 1992 PPP$).

Note: values in parentheses represent welfare gains from policy reform relative to BAU in 2010.

Table 4 (continued): Impact of Coordinated Trade and Environmental Policy Reforms on Mortality and Morbidity Health Damages for Santiago (in 1992 PPP$)

	Aggregate Abatement of 25% by Type of Effluent												
Health	**toxair**	**toxwat**	**toxsol**	**bioair**	**biowat**	**biosol**	**so2**	**no2**	**co**	**voc**	**part**	**bod**	**tss**
Mortality	691	607	704	718	109	755	(804)	(802)	131	11	(901)	701	683
Morbidity	193	109	224	(71)	(764)	452	(3)	(6)	(90)	(79)	(397)	225	488
Total	884	716	927	647	(656)	1,207	(806)	(808)	41	(68)	(1,297)	927	1,171
Total (% Chile BAU	0.46	0.37	0.48	0.34	(0.34)	0.63	(0.42)	(0.42)	0.02	(0.04)	(0.68)	0.48	0.61

Note: All mortality and morbidity figures are valued at a reference level of GDP/capita income in 2010 under BAU (measured in 1992 PPP$).

Note: values in parentheses represent welfare gains from policy reform relative to BAU in 2010.