PART B

CASE STUDIES

CHAPTER 6

GROWTH, TRADE, AND THE ENVIRONMENT NEXUS IN CHILE: A COMPREHENSIVE ASSESSMENT

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1. INTRODUCTION

This chapter is a synthesis of two studies of the interface between growth, trade, and the environment in Chile. Our two investigations complement earlier analyses of the trade-environment nexus in Latin America, which focused on the potential emergence of pollution havens (Birdsall and Wheeler 1992), and recent environmental studies of Chile, which centre on urban air pollution with little or no linkage to trade orientation (O'Ryan 1994; Sanchez 1992; The World Bank 1994; O'Ryan and Sanchez 2001). Our first study focuses on pollution emissions and natural resource use; our second study takes the pollution emissions a step further and analyses the implications of the trade-environment interface for ambient pollution in Santiago and public health and damages.[1] The two studies rely on the methodology presented in the first part of the book (Chapters 3 and 4). In addition, the investigation of the health implications and their valuation is based on Chapter 5.

The Chilean computable general equilibrium (CGE) model comprises 75 sectors. The environment is characterised by pollution emissions linked to economic activity, natural resource use, and public health implications of urban air pollution. The model incorporates 13 measures of pollution effluents, which are linked to the use of polluting inputs and energy use. We derive health implications for six measures of ambient pollution in Santiago using numerous mortality and morbidity measures.

Because its topology, local climate, and economic concentration make this urban area comparable to Mexico City, Mexico, and Jakarta, Indonesia, pollution in Santiago poses a major and lasting environmental challenge to Chilean policymakers. A second motivation for the Chilean study is to make more tangible the linkages between economic, environmental, and public health indicators, building upon recent work on urban pollution and health in Santiago (The World Bank 1994; Ostro et al. 1995; O'Ryan 1994, Comision National del Medio Ambiente 1998). This is an essential step in support of policy formulation that takes more explicit account of economy-environment linkages and assesses direct and immediate personal costs of environmental degradation. We quantify the incremental mortality and morbidity associated with combined economic and environmental policies and their monetary damages.

The Chilean case study is also interesting because it considers several trade integration scenarios via regional agreements and unilateral liberalisation. Regional agreements induce different patterns of specialisation from unilateral trade liberalisation and hence different pollution and environmental patterns as well. Specifically, we consider trade integration scenarios by way of Chile's accession to the North American Free Trade Agreement (NAFTA), the Common Market of the Southern Cone of South America (MERCOSUR), and unilateral opening to world markets.

We find that emissions of small particulates less than 10 micrograms in size (PM-10), sulphur dioxide (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 NAFTA appears to be environmentally benign. NAFTA participation, relative to unilateral trade liberalisation, provides a reduction in environmental damages, an unintended benefit from trade diversion, which reduces the reliance on cheap energy under free trade. Integration through unilateral liberalisation has a negative effect on the environment and upon urban morbidity and mortality. Damages from rising morbidity and mortality are substantial. Integration based on unilateral trade liberalisation induces damages equal to 8 per cent of the income gains arising from the trade integration. Unilateral trade integration combined with a tax on small particulates brings welfare gains that are about 16 per cent higher than those obtained under unilateral trade reform alone.

Finally, our results, with some qualifications, strongly support the existence of a double-dividend conjecture on joint environment and efficiency gains. Taxing air pollutants while reducing trade distortions and maintaining revenue neutrality induces net welfare gains from both reduced health damages and a more efficient allocation of resources by markets. Hence, reducing pollution by swapping pollution taxes for trade taxes would pay for itself in Chile.

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, Choksi, and Michaely 1990; The World Bank 1994).[2] 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 (The World Bank 1994).

Urbanisation is already well advanced in Chile, where about 85 per cent of the population live in or within the vicinity of major cities (for example, the Santiago metropolitan area and Valparaiso). The income growth and rapid urbanisation 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 (The 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 (thermic inversion) puts Santiago in the league of the most polluted cities in the world.[3] Rising income and health concerns are at odds with this situation. With the assistance of international organisations, Chile started addressing these environmental problems in the early 1990s, especially, air and water pollution in Santiago and the depletion of forest resources (see The World Bank 1994; Comision National del Medio Ambiente 1998; and O'Ryan and Sanchez 2001).

Next, we present a non-technical summary of the unique features of the Chilean model, namely the added health module and valuation of the health impact of pollution. Then we describe the results of various trade scenarios. We stress the implications for natural resource use, emissions, and ambient pollution in Santiago and the associated health impacts.

2. THE TEQUILA MODEL FOR THE CHILEAN STUDY

The Trade and Environment Equilibrium Analysis (TEQUILA) model presented in Chapter 3 is tailored for this investigation. Natural sectors are represented by five agricultural sectors, forestry, fisheries, and five mining and 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 industries.

Trade is modelled assuming goods are differentiated with respect to region of origin and destination. The disaggregation of trade flows allows us to analyse NAFTA and MERCOSUR scenarios. On the import side, we account for the heterogeneity of imports and domestic goods with the constant-elasticity-of-substitution (CES) specification attributed to Armington. We assume a constant-elasticity-of-transformation (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 with two exceptions. We assume that copper and fishmeal exporters face a finite demand with an own-price elasticity of -5. 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 adjustment reforms.

As in the other investigations presented in this book, a vector of 13 measures of various water, air, and soil effluents characterises pollution by sector. The intensities vary 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, carbon monoxide (CO), volatile organic compounds (VOC), and particulate intensity (PART); and, finally, water pollution measured by biological oxygen demand (BOD) and total suspended solids (TSS).

The model maps the predicted national pollution emissions from our simulations into health effects for residents in Santiago and then into monetary damages corresponding to health impacts of pollution. In characterising emissions we use inventory baseline information on major air pollutants and emission sources. This step involves collecting existing information on pollutants known to cause significant 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 emissions for the whole economy attributable to Santiago as well as to calibrate the health module of the economy-wide model to initial conditions.

Dispersion modelling maps the effluent emissions into ambient concentration levels. We pay extra attention to two major air pollutants that bear significantly on our results: PM-10 and lead. For PM-10, recent ambient concentration data for Santiago indicate significant reductions since the early 1990s. We therefore assume that policy will have a significant impact on particulate emissions over the scenario period, in particular, that the sectoral emission coefficients will decline at a rate of 3 per cent per annum to 2010. For lead, we apply the regulation on lead content of gasoline in Santiago of 0.18 grams per litre, which was effective from 1995, to base-year gasoline consumption in order to estimate motor vehicle related lead emissions. Then we allocate the lead emissions not accounted for by gasoline in the base year to other sectors in accordance with the U.S. coefficients, constraining total Santiago emissions to yield the average ambient concentration of 1.5 milligrams per cubic metre given the dispersion function. Chile intends to phase down leaded gasoline use over time; therefore, we incorporate a 75 per cent reduction in the transport sector emission coefficient for lead for the period to 2010. Despite these assumptions, lead emissions grow significantly in the baseline. This is caused by the high-income elasticity of demand for transport services and also by the growth of lead-emitting industrial sectors. The non-transport sector emission coefficients are kept constant at their base-year values, given that we do not make conjectures on policy initiatives relating to lead sources other than gasoline combustion.

Population-weighted concentration levels are then used to determine exposure rates for health impacts. The next step involves calculating the physical response of human resources 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 endpoints presented in the results section have to be interpreted as the increase/decrease in mortality and morbidity with respect to the business-as-usual (BAU) levels of mortality and morbidity. We look at various morbidity and mortality incidences: premature mortality due to PM-10, SO_2, and ozone; premature mortality in males of age 40-59 years due to lead; respiratory hospital admissions (for PM-10, ozone); emergency room visits (for PM-10); restricted activity days (for PM-10); lower respiratory illness for children population of age under 17 years (PM-10); asthma symptoms for asthmatic population (for PM-10, ozone); respiratory symptoms (for PM-10, ozone); chronic bronchitis in population of age 25 years or older (for PM-10); minor restricted activity days (for ozone); respiratory symptoms in children population (for SO_2); chest discomfort in adult population (for SO_2); respiratory symptoms in adult population (for NO_2); eye irritation in adult population (for ozone); number of headaches in adult population (for CO); IQ decrement in children population (for lead); cases of hypertension in adult male population (for lead); and non-fatal heart attacks in male population age 40-59 (for lead).

The last step is to attach a monetary value to these health impact figures. We follow the willingness-to-pay approach to value morbidity and loss of life due to a change in mortality, as presented in detail in Chapter 5. We rely on the large body of information and data on such willingness-to-pay measures for industrialised economies to estimate these damages. 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 (see Chapter 5 and Bowland and Beghin 2001).

Our estimates of willingness-to-pay measures for morbidity are less sophisticated because of the scarcity of estimates available per measure of morbidity in industrialised countries. Hence, the procedure followed for mortality is ruled out. The available estimates from industrialised countries are scaled down to reflect the per capita income differences between Chile and these industrialised countries, expressed in purchase-power-parity 1992 dollars.

3. POLICY REFORM SCENARIOS

The time horizon of the simulations is the period 1992-2010 but with the policy reforms starting in 2000. Every year, savings determine the pool of new investment for the next period and the model solves for equilibrium for the year. This equilibrium determines savings going towards the new investment pool for the subsequent period. Each period, the sectoral resource allocation adjusts to new prices. Labour moves freely across sectors; existing capital is reallocated across sectors but to a lesser extent, due to the partial mobility assumption built into the model. The endogenous variables of interest, which adjust at every period, are sectoral output and input use, consumption, trade, pollution emissions associated with production and consumption, and aggregate real income, which serves as an approximate gauge of welfare or market efficiency.

As in the other studies, we define a BAU trajectory for the economy until 2010. Factor and energy productivity changes are endogenously determined such that the gross domestic product (GDP) forecast and the model are consistent with each other. All policies are held constant in this reference BAU scenario. For the years 1992 to 2010, the model gives us BAU trajectories for output, absorption, trade, and pollution emissions. All reported results are expressed in deviations (in percentages) 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 a time. Each tax is such that the emissions of the targeted pollutant progressively decrease over time and reach a 25 per cent decrease relative to their level in the BAU results by 2010. The taxes are imposed on inputs and are proportional to the effluent content of the inputs. These taxes are phased in such as to obtain gradual reductions, culminating in a 25 per cent decrease 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 gradual trade integration, combining unilateral trade liberalisation through tariff reductions with a concurrent but modest improvement in 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 in the terms of trade. We decrease the ad valorem tariffs progressively to free trade, i.e., from their reference levels in 2000 to no tariff in 2010. Terms-of-trade improvements are expressed as a progressive increase in observed world prices for exports by 10 per cent 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 liberalisation scenarios with NAFTA and MERCOSUR countries. Disaggregated data on trade flows allow us to consider these alternative trade-liberalisation 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 that are members of these two regional agreements. Our objective is to impose a sizable trade shock on the Chilean economy in order to estimate changes in sectoral composition of production and trade. These changes determine the pollution emitted and induced by the outward trade orientation.

As in the other country case studies, 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. The differences in the incentive structures lead one to expect contrasting results concerning the indirect abatement or exacerbation achieved through complementarity or substitution among emission types, which occurs under the two scenarios.

4. RESULTS FROM POLICY REFORM SIMULATIONS

Results follow the sequence of the three reform scenarios: environmental tax reform, trade integration (unilateral, NAFTA, and MERCOSUR), and then combined trade integration and environmental protection. In this section, we narrate salient results of the simulations in aggregate. Tables 1, 5, and 9 show the impact of the three policy reform scenarios on aggregate indicators. Tables 2, 6, and 10 sequentially show the effects of the three scenarios on pollution emissions for the economy and for Santiago. Tables 3, 7, and 11 show how pollution in Santiago affects the health status of its population for the three scenarios respectively. Tables 4, 8, and 12 show the estimated valuation of the three scenarios' health impact.

4.1. Effluent Taxes

All effluent taxes but the one on BIOAIR have a negative impact on growth. These effects are small (less than 1 per cent), except for the tax on toxic emissions, BOD emissions, and BIOWAT emissions, which have a larger impact in absolute value (Table 1). The pollution tax on BIOAIR has a very small positive impact on real GDP. Hence, the strong tendency towards a reduction of aggregate output with budget-neutral environmental taxes indicates that these policy reforms "do not pay" for themselves in the narrow efficiency sense (Goulder 1995). 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. With the latter, trade decreases by about 9 per cent and investment decreases by 23 per cent. The moderate aggregate output effect of the environmental taxes dissimulates substantial variations at the disaggregated sectoral level and reallocation of resources across sectors.

Next we look at noticeable sectoral output effects, i.e., substantial changes in output occurring in some of the 72 disaggregated sectors included in the model (not presented in the tables). For the first four taxes (all three toxics and BIOAIR), fish and seafood output increases significantly but mining activities decrease sharply. The tax on BIOWAT has a negative effect on virtually all sectors, and it has an especially strong effect on iron, coal, and basic metals. Aggregate trade contracts with the effluent taxes. At the disaggregated sectoral levels, trade effects are mixed. Importing is a way to abate pollution occurring in

Table 1. Impact of environmental policy reform on aggregate variables (percentage)

Aggregate Variables	*Aggregate Abatement of 25 Per Cent by Type of Effluent Emission*												
	TOXAIR	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Real GDP	-1.91	-2.09	-1.92	0.03	-7.61	-0.42	-0.20	-0.19	-0.07	-0.45	-0.18	-1.91	-0.01
Production	-2.90	-3.24	-2.82	-0.44	-7.63	-0.73	-2.03	-2.00	-0.70	-2.70	-1.81	-2.81	-0.12
Consumption	-1.28	-1.58	-1.28	-0.18	-1.27	0.15	-0.99	-0.97	-0.13	-1.69	-0.60	-1.31	0.05
Investment	-5.70	-6.25	-5.68	-0.09	-23.39	-1.25	-1.36	-1.32	-0.54	-2.04	-1.32	-5.66	-0.08
Exports	-3.81	-4.35	-3.79	1.13	-9.57	-0.63	-3.37	-3.31	-0.78	-2.04	-2.43	-3.82	-0.01
Imports	-1.82	-2.37	-1.91	1.36	-9.12	0.72	-3.54	-3.46	-0.76	-1.78	-2.44	-1.98	0.03
Labour supply	-0.78	-0.81	-0.77	0.08	-2.78	-0.28	0.35	0.32	0.07	-0.09	0.20	-0.76	-0.02
Capital supply	-2.43	-2.69	-2.44	-0.03	-9.69	-0.50	-0.51	-0.49	-0.21	-0.64	-0.51	-2.44	-0.04
Real income	-1.45	-1.77	-1.46	-0.17	-1.18	0.18	-0.95	-0.94	-0.12	-1.96	-0.58	-1.48	0.05
Absorption	-2.86	-3.24	-2.78	-0.40	-7.34	-0.56	-2.02	-1.99	-0.66	-2.92	-1.75	-2.78	-0.10

production, and exporting reduces the pollution linked to consumption. These sectoral effects are moderate.

As indicated in Table 2, pollution abatement induced by each effluent tax 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, given that 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. This is the case for the following subgroups: all toxics, BIOWAT and BIOSOL, and SO_2, NO_2, and PART (PM-10). More intriguing is the presence, in the aggregate, of substitution possibilities among effluents. For example, SO_2 and NO_2 are substitutes for TSS.

The tax rates implied by the targeted decrease in emissions are realistic when expressed in an ad valorem equivalent of the producer price. On average, the pollution tax per unit of sectoral output is 4 per cent or less for all 13 scenarios. The individual tax rates (per sector and by effluent) vary from zero to less than 15 per cent for all 13 scenarios, except for the scenario targeting reductions in VOC. In the latter scenario, the pollution tax rate on wine and liquors and on furniture products jumps above 50 and 35 per cent, respectively. These high rates are caused by the fact that these two sectors account for most of the VOC pollution in production.

In the decomposition of the abatement, the composition effect is overwhelming both in the abatement in production and in consumption. The effect is more substantial in production than in consumption, because 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 in the case of the BIOWAT tax (with a production scale effect of -8.1 per cent).

The impact of the effluent taxes on the effluent concentration in Santiago is diverse and generally follows the complementarity patterns observed for emissions. Table 2 shows that taxes on VOC, SO_2, NO_2, and PART (PM-10) provide significant decreases in lead (between 6 and 7 per cent). The taxes on BIOAIR and BIOWAT also decrease lead concentrations (by 11.4 and 5.3 per cent respectively). The tax on BIOWAT has negative and sometimes large effects on other concentrations as well—it 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 lead to a substantial decrease in the concentrations of the other two and some decrease in CO. Taxes on CO and VOC also achieve substantial decreases in concentration in Santiago through a reduction of energy use and through a reduction in ozone. The other taxes have a marginal impact on most of the concentrations.

In Table 3, the health endpoint changes are striking for the taxes on SO_2, NO_2, and PM-10. Premature mortality reductions are between 15 and 22 per cent. With these three taxes, most endpoints show improvements, with decreases of morbidity between 10 and 27 per cent for most of the morbidity measures.

Table 2. Impact of environmental policy reform on national effluent emissions and Santiago ambient pollution (percentage)

Scenario	*Aggregate Abatement of 25 Per Cent Type of Effluent Emission*												
	TOXAIR	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*	*BOD*	*TSS*
National emissions													
TOXAIR	-25.0	-26.0	-24.2	0.0	-10.9	-10.2	-2.1	-2.1	-1.0	-4.0	-2.7	-24.1	-0.5
TOXWAT	-23.7	-25.0	-23.1	-0.1	-10.8	-8.6	-3.3	-3.2	-1.1	-4.8	-3.2	-23.0	-0.3
TOXSOL	-25.7	-26.8	-25.0	0.1	-11.3	-9.9	-1.8	-1.8	-0.9	-3.8	-2.4	-24.9	-0.4
BIOAIR	-2.3	-3.0	-1.9	-25.0	-9.4	-0.8	-12.7	-12.4	-6.8	-14.7	-14.0	-1.8	-2.5
BIOWAT	-6.7	-7.0	-6.5	-0.7	-25.0	-2.0	-0.2	-0.1	-4.3	-1.4	-5.2	-6.5	-2.1
BIOSOL	-30.6	-29.7	-28.6	-0.4	-11.8	-25.0	0.6	0.3	-1.6	-2.5	-2.6	-27.8	-1.0
SO_2	-3.8	-5.8	-3.3	-3.8	-4.8	-0.1	-25.0	-24.9	-4.0	-10.2	-16.5	-3.3	0.5
NO_2	-3.7	-5.7	-3.1	-3.8	-4.6	-0.2	-25.0	-25.0	-4.0	-10.1	-16.5	-3.1	0.5
CO	-6.3	-6.5	-5.4	-6.2	-28.9	-2.6	-7.5	-7.4	-25.0	-4.4	-33.1	-5.3	-12.0
VOC	-3.8	-4.9	-3.5	-1.3	-3.3	-0.4	-3.3	-3.3	-0.5	-25.0	-2.1	-3.5	0.1
PART	-5.0	-6.1	-4.3	-4.8	-15.8	-1.5	-15.7	-15.7	-13.6	-7.1	-25.0	-4.3	-5.4
BOD	-25.7	-26.9	-25.0	0.1	-11.4	-9.5	-1.9	-1.8	-0.9	-3.8	-2.4	-25.0	-0.4
TSS	-12.1	-10.7	-10.7	-9.3	-52.9	-6.6	9.9	9.9	-46.6	0.8	-50.8	-10.5	-25.0
Santiago concentrations													
Lead	-2.8	-3.3	-2.6	-11.4	-5.3	-1.0	-6.7	-6.6	-3.2	-6.2	-7.0	-2.5	-1.1
SO_2	-2.0	-3.4	-1.6	-2.6	-3.9	0.4	-17.8	-17.7	-2.8	-7.5	-11.6	-1.6	0.4
NO_2	-2.0	-3.6	-1.6	-2.9	-4.2	0.4	-19.9	-19.8	-3.1	-8.3	-13.0	-1.6	0.5
CO	-5.8	-5.9	-5.0	-5.6	-31.7	-2.6	-5.4	-5.3	-26.7	-3.9	-34.3	-4.9	-12.7
VOC	-2.4	-3.1	-2.1	-0.7	-2.7	-0.1	-2.9	-2.9	-0.5	-18.6	-1.9	-2.1	0.1
PM-10	-4.5	-5.5	-3.8	-4.7	-18.8	-1.4	-14.3	-14.2	-15.4	-7.0	-27.0	-3.8	-6.2
Ozone	-1.8	-2.7	-1.6	-1.2	-2.6	0.1	-7.4	-7.3	-1.1	-12.4	-4.8	-1.6	0.2

Table 3. Impact of environmental policy reform on health endpoints for Santiago (percentage)

	Aggregate Abatement of 25 Per Cent by Type of Effluent Emission												
Scenario	*TOXAIR*	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	SO_2	NO_2	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Premature mortality/100,000/Year	-3.8	-4.9	-3.2	-4.0	-14.4	-0.8	-15.3	-15.2	-11.7	-7.2	-22.4	-3.1	-4.3
Premature mortality/1 million males age 40-59	-2.8	-3.3	-2.6	-11.4	-5.3	-1.0	-6.7	-6.6	-3.2	-6.2	-7.0	-2.5	-1.1
RHA/Year	-3.1	-4.0	-2.6	-2.8	-10.2	-0.6	-10.6	-10.5	-7.8	-9.9	-15.2	-2.6	-2.8
ERV/Year	-4.5	-5.5	-3.8	-4.7	-18.8	-1.4	-14.3	-14.2	-15.4	-7.0	-27.0	-3.8	-6.2
RAD/Year	-4.5	-5.5	-3.8	-4.7	-18.8	-1.4	-14.3	-14.2	-15.4	-7.0	-27.0	-3.8	-6.2
LRI/Year (children < age 17)	-4.5	-5.5	-3.8	-4.7	-18.8	-1.4	-14.3	-14.2	-15.4	-7.0	-27.0	-3.8	-6.2
Asthma attacks/year (Asthmatics)	-2.4	-3.3	-2.1	-1.9	-6.1	-0.2	-8.9	-8.8	-4.2	-11.2	-9.6	-2.1	-1.2
Respiratory symptoms/year	-3.6	-4.5	-3.1	-3.4	-13.2	-0.9	-11.9	-11.8	-10.5	-8.9	-19.3	-3.0	-4.0
Chronic bronchitis/year	-4.5	-5.5	-3.8	-4.7	-18.8	-1.4	-14.3	-14.2	-15.4	-7.0	-27.0	-3.8	-6.2
MRAD/year	-1.8	-2.7	-1.6	-1.2	-2.6	0.1	-7.4	-7.3	-1.1	-12.4	-4.8	-1.6	0.2
Respiratory symptoms/year (children)	-2.0	-3.4	-1.6	-2.6	-3.9	0.4	-17.8	-17.7	-2.8	-7.5	-11.6	-1.6	0.4
Chest discomfort episodes/year	-2.0	-3.4	-1.6	-2.6	-3.9	0.4	-17.8	-17.7	-2.8	-7.5	-11.6	-1.6	0.4
Respiratory symptoms/year (adults)	-2.0	-3.6	-1.6	-2.9	-4.2	0.4	-19.9	-19.8	-3.1	-8.3	-13.0	-1.6	0.5
Eye irritations/year (adults)	-1.8	-2.7	-1.6	-1.2	-2.6	0.1	-7.4	-7.3	-1.1	-12.4	-4.8	-1.6	0.2
Headaches/year	-5.8	-5.9	-5.0	-5.6	-31.7	-2.6	-5.4	-5.3	-26.7	-3.9	-34.3	-4.9	-12.7
IQ decrements	-2.8	-3.3	-2.6	-11.4	-5.3	-1.0	-6.7	-6.6	-3.2	-6.2	-7.0	-2.5	-1.1
Cases of hypertension/1 million males age >20	-2.8	-3.3	-2.6	-11.4	-5.3	-1.0	-6.7	-6.6	-3.2	-6.2	-7.0	-2.5	-1.1
Non-fatal heart attacks/1 million males age 40-59	-2.8	-3.3	-2.6	-11.4	-5.3	-1.0	-6.7	-6.6	-3.2	-6.2	-7.0	-2.5	-1.1

Notes: Respiratory Hospital Admissions (RHA), Emergency Room Visits (ERV), Restricted Activity Days (RAD), Lower Respiratory Illness (LRI), Minor Restricted Activity Days (MRAD)

Table 4 presents the health damage reductions induced by each environmental tax. The tax on PART (PM-10) induces a decrease in monetary damages equivalent to 0.69 per cent of the BAU 2010 GDP; taxes on SO_2 and NO_2 reduce damages by an amount equivalent to about 0.50 per cent of BAU 2010 GDP. The latter taxes induce net gains, as approximated by the loss of aggregate income plus the reduction in damages; this is also true of the tax on BIOAIR. The estimated welfare gains are lower-bound estimates because the decreases in morbidity and mortality are applied only to Santiago's population. Hence, we find evidence of a net welfare gain (a double dividend) when accounting for health damages. These gains are rather small, in part because we only value health benefits for a subset of the Chilean population. The gains are conditioned on the various assumptions built into the model.

4.2. Trade Integration

According to Table 5, unilateral integration with world markets induces the largest increase in real GDP (4.86 per cent), followed by regional integration via NAFTA (1.4 per cent) and MERCOSUR (0.52 per cent). These gains are small, representing the relative gains over 10 years. These small changes originate in the outward orientation Chile has been following; large gains from liberalisation have already occurred. Nevertheless, these reforms have significant positive impacts on aggregate trade and aggregate gross investment.

Moving to disaggregated 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, copper, fishmeal, glass, and other manufacturing contract with undistorted trade. With NAFTA integration, fruit, agricultural services, other mining, food processing except fishmeal, and wine and liquor would expand significantly, whereas copper, iron, and paper would decrease. Hence, NAFTA integration departs significantly from integration with all partners in terms of international specialisation. MERCOSUR integration does not induce any strong effect, except for a major increase in food processing other than fishmeal, an increase in transportation material, and a decrease in iron and copper production.

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 and exports of fishmeal and copper. NAFTA integration has a smaller effect on trade than does unilateral reform. There are noticeable export increases for food processing, wine, and textile and apparel, and decreases for iron, copper, forestry, and fishmeal. Imports of agriculture, livestock, forestry, mining sectors, and wood products expand as well. Finally, the MERCOSUR integration induces increases in imports of agricultural products, iron, oils, sugar, tobacco, petroleum refining, and met-

Table 4. Impact of environmental policy reform on health damages

	Aggregate Abatement of 25 Per Cent Type of Effluent Emission												
Scenario	*TOXAIR*	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	SO_2	NO_2	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Health damages						*(million PPP$)*							
Mortality	-377.2	-459.8	-334.5	-1072.9	-996.5	-114.3	-1150.8	-1136.4	-719.6	-784.4	-1452.0	-328.9	-258.4
Morbidity	-104.8	-128.8	-89.2	-108.1	-409.8	-28.7	-336.9	-334.8	-330.7	-207.4	-592.1	-88.2	-130.7
Total	-482.0	-588.6	-423.7	-1181.0	-1406.3	-143.1	-1487.7	-1471.2	-1050.3	-991.8	-2044.1	-417.0	-389.1
% of GDP BAU (4)	-0.16	-0.20	-0.14	-0.40	-0.47	-0.05	-0.50	-0.49	-0.35	-0.33	-0.69	-0.14	-0.13
Impact of reform on market allocation						*(percentage)*							
Real GDP change (5)	-1.91	-2.09	-1.92	0.03	-7.61	-0.42	-0.20	-0.19	-0.07	-0.45	-0.18	-1.91	-0.01
Total gains (5)-(4)	-1.75	-1.89	-1.77	0.43	-7.14	-0.37	0.30	0.30	0.29	-0.12	0.50	-1.77	0.12

Table 5. Impact of trade policy reform on aggregate variables (percentage)

Aggregate Variables	*Trade Policy Reform*[a]		
	Unilateral	*NAFTA*	*MERCOSUR*
Real GDP	4.86	1.40	0.52
Production	6.42	1.38	0.89
Consumption	8.87	2.25	0.87
Investment	16.50	4.24	1.66
Exports	17.68	3.61	2.99
Imports	29.27	6.21	4.48
Labour supply	1.56	0.82	0.20
Capital supply	6.27	1.63	0.64
Real income	9.28	2.43	0.92
Absorption	8.66	1.95	1.09

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

als; imports of fish would decrease. On the export side, substantial reductions occur in exports of fishmeal, iron, copper, and seafood, but food processing, chemicals, plastics, and printing expand significantly. The endogenous world price assumption for fishmeal and copper accentuates the contraction of these two industries that already occurred under the small-country assumption.

Table 6 shows the contrasting pollution implications of these trade reforms. Unilateral integration is pollution intensive; for example, NO_2, SO_2, and PM-10 have elasticity with respect to GDP between 3 and 4 under this scenario. In contrast, NAFTA has elasticity values around 2 and 2.1, respectively, for the same effluents. The moderate expansion of pollution under MERCOSUR is matched by a moderate GDP expansion resulting in an air pollution intensive integration. However, MERCOSUR and unilateral integrations bring a decrease in BIOAIR induced by cheaper imports of natural gas. The trade diversion of NAFTA integration mitigates emissions relative to the other two trade integration scenarios. This is an unexpected, if not overlooked, insight on trade diversion in the presence of externalities. The NAFTA scenario produces strong composition effects in production, outweighing the scale expansion induced by NAFTA. In contrast, the unilateral integration relative to all partners induces higher intensities in SO_2, NO_2, and PART (PM-10) via strong technical effects towards pollution-intensive input combinations. In addition to large increases in SO_2, NO_2, and PART, unilateral integration brings increases for all toxics, BIOWAT, CO, VOC, BOD, and TSS (Table 6). These increases are observed after 10 years of expected growth and therefore do not represent anything dramatic.

Table 6. Impact of trade policy reform on national effluent emissions and Santiago ambient pollution (percentage)

	Trade Integration		
	Unilateral	*NAFTA*	*MERCOSUR*
National emissions			
TOXAIR	6.5	2.4	0.6
TOXWAT	8.0	2.4	0.7
TOXSOL	6.7	2.4	0.5
BIOAIR	-6.0	0.4	-0.9
BIOWAT	13.7	3.3	1.3
BIOSOL	-3.3	1.2	-0.3
SO_2	19.4	2.8	2.0
NO_2	19.3	2.9	2.0
CO	11.6	1.6	0.8
VOC	11.5	3.4	1.2
PART	15.1	2.4	1.3
BOD	7.0	2.4	0.6
TSS	2.4	1.3	-0.6
Santiago concentrations			
Lead	0.8	0.8	0.4
SO_2	14.3	1.1	1.7
NO_2	15.8	1.3	1.9
CO	11.5	0.9	0.8
VOC	8.8	2.3	1.0
PM-10	15.3	1.6	1.5
Ozone	9.2	1.6	1.1

For the health endpoints in Santiago, the unilateral integration scenario has negative consequences for both mortality and all measures of morbidity as shown in Table 7. Premature mortality due to PM-10, ozone, and SO_2 increases by 15 per cent and premature death in males of age 40-59 due to lead increases marginally. Morbidity increases are significant except for IQ decrements, hypertension, and non-fatal heart attacks. NAFTA and MERCOSUR induce marginal increases in the health endpoints. The damages associated with the health incidences are substantial for the unilateral trade integration. As suggested by Table 8, the damages represent about 8 per cent of the aggregate income gains induced by trade integration (damages as a percentage of gains in GDP). By contrast the damages under the NAFTA scenario are moderate given the small deterioration of the average health status in Santiago.

Table 7. Impact of trade policy reform on health endpoints for Santiago (percentage)

	Trade Integration		
Scenario	*Unilateral*	*NAFTA*	*MERCOSUR*
Premature mortality/100,000/year	15.0	1.4	1.5
Premature mortality/1 million males age 40-59	0.8	0.8	0.4
RHA/year	12.0	1.6	1.3
ERV/year	15.3	1.6	1.5
RAD/year	15.3	1.6	1.5
LRI/year (children < age 17)	15.3	1.6	1.5
Asthma attacks/year (asthmatics)	10.5	1.6	1.2
Respiratory symptoms/year	13.2	1.6	1.3
Chronic bronchitis/year	15.3	1.6	1.5
MRAD/year	9.2	1.6	1.1
Respiratory symptoms/year (children)	14.3	1.1	1.7
Chest discomfort episodes/year	14.3	1.1	1.7
Respiratory symptoms/year (adults)	15.8	1.3	1.9
Eye irritations/year (adults)	9.2	1.6	1.1
Headaches/year	11.5	0.9	0.8
IQ decrements	0.8	0.8	0.4
Cases of hypertension/1 million males age >20	0.8	0.8	0.4
Non-fatal heart attacks/1 million males age 40-59	0.8	0.8	0.4

Notes: Respiratory Hospital Admissions (RHA), Emergency Room Visits (ERV), Restricted Activity Days (RAD), Lower Respiratory Illness (LRI), Minor Restricted Activity Days (MRAD)

4.3. Coordinated Trade Integration and Environmental Protection

We first combine NAFTA integration and effluent taxes on air pollutants. Then, we consider unilateral trade integration coordinated with an effluent tax on one pollutant at a time. The effluent taxes are designed as in the first set of scenarios on environmental reforms, that is, incremental and leading to a 25 per cent decrease in emissions of the taxed effluent with respect to their BAU levels. The tax rates corresponding to these reforms are slightly higher than in the environmental reforms alone. The average tax rates on pollution, expressed in percentage of the producer price per unit of output, do not exceed 6 per cent. With trade integration, the pollution expansion requires higher tax rates than those reached under the environmental reform alone, in order to go back to a pollution level corresponding to a 25 per cent decrease with respect to the BAU level. With

Table 8. Impact of trade policy reform on health damages

	Trade Liberalisation		
Scenario	*Unilateral*	*NAFTA*	*MERCOSUR*
Health damages		*(million PPP$)*	
Mortality	657.9	125.1	90.6
Morbidity	363.2	40.8	36.1
Total	1021.1	165.9	126.6
% of GDP BAU (4)	0.34	0.06	0.04
Impact of reform on market allocation		*(percentage)*	
Real GDP change (5)	4.86	1.40	0.52
Total gains (5)-(4)	4.52	1.35	0.48

these higher rates, substitution/complementarity relationships between pollutant types are exacerbated.

Table 9 shows that the aggregate effect of the combined reforms (NAFTA *cum* effluent tax) is small in general, but it is positive on real GDP in all cases. This positive real income effect suggests that with this larger policy menu (trade and environmental distortions) the environmental reform pays for itself, even before accounting for the associated health benefits. The aggregate effects also differ according to the pollutant considered. For example, the effluent tax on CO has a positive effect on aggregate measures, whereas the tax on VOC has a negative impact on production and absorption. As shown in Table 10, most of the pollution abatement figures, including the multiplier effects of the tax on pollutants that are not directly targeted by the tax, are similar to the abatement figures obtained under the environmental reforms alone. The indirect abatement of the pollutants other than the targeted one does not have to occur because changing border prices affect specialisation and hence pollution. This result is due to the fact that NAFTA integration has a mitigated impact on the Chilean environment.

According to Table 9, the impact of coordinated unilateral trade integration with environmental taxes appears almost additive on real GDP, trade, and consumption. This is a recurrent result in this type of simulation exercise (see Chapter 10). Aggregate trade expands less under the coordinated reforms than under the simple unilateral trade integration, although some sectoral imports induced by the latter reform grow even more under the coordinated scenario because imports are a way to abate pollution. For instance, fish imports are larger under the combined scenario than under the unilateral trade integration alone.

The inventory of emissions duplicates several patterns reached under the single effluent tax reform. As is evident from Table 10, all three toxic effluents are complementary to each other; so too are the air pollutants SO_2, NO_2, and PART (PM-10). Nevertheless, air pollutants (SO_2, NO_2, VOC, PM-10, and CO) be-

Table 9. Impact of combined trade and environmental policy reforms on aggregate variables (percentage)

Aggregate Variables	*Combined NAFTA and Environmental Policy Reform*[a]					
	BIOAIR	*NO_2*	*SO_2*	*CO*	*VOC*	*PART*
			(percentage)			
Real GDP	1.44	1.18	1.17	1.33	0.89	1.19
Production	0.92	-0.86	-0.88	0.58	-1.67	-0.69
Consumption	2.06	1.15	1.13	2.10	0.29	1.55
Investment	4.15	2.72	2.68	3.66	1.92	2.74
Exports	4.77	-0.07	-0.12	2.73	1.29	0.85
Imports	7.63	2.32	2.28	5.39	4.13	3.43
Labour Supply	0.91	1.15	1.16	0.89	0.70	1.03
Capital Supply	1.59	1.07	1.06	1.40	0.91	1.06
Real Income	2.25	1.37	1.35	2.29	0.17	1.76
Absorption	1.54	-0.29	-0.31	1.20	-1.40	-0.07

Table 9. Extended

Aggregate Variables	*Unilateral Trade Integration Combined with Aggregate Abatement of 25 Per Cent by Type of Effluent Emission*												
	TOXAIR	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Real GDP	2.57	2.27	2.59	4.89	-7.09	4.50	4.48	4.49	4.75	4.17	4.50	2.59	4.85
Production	2.86	2.31	3.02	6.07	-5.69	5.82	2.85	2.90	4.87	2.26	3.09	3.04	6.29
Consumption	6.98	6.50	7.05	8.67	6.42	8.91	6.99	7.03	8.44	5.99	7.56	7.02	8.92
Investment	8.88	7.86	9.04	16.43	-22.09	15.43	13.71	13.80	15.19	12.92	13.78	9.07	16.41
Exports	13.09	12.31	13.18	18.61	1.22	17.29	11.23	11.34	15.41	13.60	12.52	13.15	17.63
Imports	26.41	25.60	26.40	30.49	11.66	30.03	21.77	21.94	26.70	25.02	23.43	26.34	29.26
Labour Supply	0.80	0.74	0.82	1.60	-2.57	1.29	2.18	2.12	1.85	1.48	1.98	0.85	1.54
Capital Supply	3.27	2.86	3.30	6.26	-9.00	5.86	5.33	5.37	5.85	5.25	5.34	3.29	6.24
Real Income	7.20	6.68	7.26	9.07	6.95	9.33	7.46	7.49	8.88	6.00	8.01	7.24	9.32
Absorption	4.83	4.19	5.01	8.30	-3.37	8.14	5.00	5.05	7.13	3.90	5.31	5.02	8.54

[a] Reflects combined policy reforms of NAFTA integration and aggregate abatement of 25 per cent by type of effluent emission.

Table 10. Impact of trade and environmental policy reform on national effluent emissions and Santiago ambient pollution (percentage)

	Combined NAFTA and Environmental Policy (25 Per Cent Reduction by Type of Effluent Emission)					
	BIOAIR	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*
National emissions						
TOXAIR	2.4	-0.1	-0.1	1.2	-2.0	-0.7
TOXWAT	2.3	-1.4	-1.4	1.2	-2.9	-1.4
TOXSOL	2.5	0.3	0.3	1.4	-1.7	-0.4
BIOAIR	-25.0	-13.5	-13.2	-6.8	-15.5	-14.7
BIOWAT	2.6	3.1	3.2	-1.3	1.7	-2.3
BIOSOL	0.9	1.1	0.8	-0.8	-1.7	-2.2
SO_2	-1.1	-25.0	-25.0	-1.7	-8.5	-15.9
NO_2	-1.0	-25.0	-25.0	-1.6	-8.4	-15.8
CO	-4.8	-6.7	-6.7	-25.0	-3.4	-34.1
VOC	2.1	-0.3	-0.3	2.9	-25.0	1.0
PART	-2.5	-15.1	-15.1	-12.1	-5.6	-25.0
BOD	2.5	0.1	0.1	1.3	-1.8	-0.5
TSS	-8.2	12.3	12.3	-47.9	2.0	-52.4
Santiago concentrations						
Lead	-10.8	-6.6	-6.5	-2.5	-5.9	-6.8
SO_2	-1.6	-18.4	-18.3	-2.1	-7.1	-12.0
NO_2	-1.6	-20.5	-20.5	-2.2	-7.8	-13.3
CO	-4.8	-4.9	-4.8	-27.6	-3.5	-35.9
VOC	1.6	-0.9	-0.9	1.8	-19.0	0.1
PM-10	-3.2	-14.1	-14.0	-15.0	-6.3	-27.9
Ozone	0.4	-6.5	-6.5	0.3	-12.5	-3.8

Table 10. Extended

Scenario	*Free Trade and Aggregate Abatement of 25 Per Cent by Type of Effluent Emission (percentage)*												
	TOXAIR	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*[a]	SO_2	NO_2	*CO*	*VOC*	*PART*	*BOD*	*TSS*
National emissions													
TOXAIR	-25.0	-27.2	-24.0	6.4	-10.5	-2.1	2.4	2.4	4.2	0.4	1.3	-24.0	5.9
TOXWAT	-22.5	-25.0	-21.6	7.9	-9.3	0.8	1.5	1.7	5.2	0.6	1.5	-21.6	7.5
TOXSOL	-26.0	-28.3	-25.0	6.7	-11.1	-1.7	3.0	3.0	4.6	0.9	1.9	-25.0	6.1
BIOAIR	-8.9	-9.9	-8.4	-25.0	-16.8	-6.8	-22.6	-22.2	-15.5	-23.6	-24.2	-8.3	-8.5
BIOWAT	4.7	3.8	5.0	13.1	-25.0	12.1	12.9	13.0	7.4	11.1	6.5	5.0	11.3
BIOSOL	-36.2	-36.0	-34.0	-3.7	-17.1	-25.0	-1.3	-2.1	-5.0	-6.1	-6.4	-33.3	-4.4
SO_2	13.3	10.0	14.3	16.2	9.4	19.3	-25.0	-24.8	6.9	1.7	-13.7	14.3	20.0
NO_2	13.5	10.3	14.5	16.1	9.6	19.1	-25.1	-25.0	6.9	1.7	-13.8	14.5	19.9
CO	2.9	2.0	4.1	6.8	-24.9	9.4	-2.0	-1.9	-25.0	4.1	-34.8	4.2	-1.5
VOC	6.4	4.7	7.0	10.5	5.8	11.2	5.8	5.9	10.3	-25.0	7.5	7.0	11.6
PART	8.0	6.0	9.0	11.2	-6.7	13.7	-12.9	-12.9	-8.0	2.8	-25.0	9.1	9.3
BOD	-25.9	-28.3	-24.9	7.1	-11.1	-0.9	3.1	3.2	4.9	1.2	2.2	-25.0	6.5
TSS	-13.6	-12.4	-11.9	-4.9	-59.6	-3.4	19.7	19.5	-58.9	4.1	-58.6	-11.7	-25.0
Santiago concentrations													
Lead	-2.9	-3.7	-2.6	-8.2	-6.0	-0.2	-9.0	-8.8	-4.0	-7.0	-9.2	-2.5	-0.4
SO_2	11.1	8.7	11.7	12.2	6.0	14.9	-17.6	-17.3	5.2	1.1	-9.4	11.7	14.9
NO_2	12.6	10.0	13.4	13.4	6.8	16.3	-19.8	-19.6	5.7	1.2	-10.7	13.4	16.4
CO	3.5	2.9	4.7	7.2	-29.1	9.5	1.4	1.6	-27.9	4.6	-36.2	4.7	-2.5
VOC	5.6	4.4	6.1	8.2	4.1	8.8	3.7	3.7	7.5	-18.5	5.1	6.1	8.9
PM-10	9.1	7.3	10.1	11.6	-10.8	14.3	-10.5	-10.3	-10.7	3.1	-27.4	10.2	8.5
Ozone	6.6	5.2	7.0	8.2	4.2	9.3	-4.0	-3.8	5.6	-9.8	-0.4	7.0	9.4

[a] Two aggregate pollutants can be substitutes under a tax on the first one but complements under a tax on the second one because only the pure substi-

tution effect (along a same isoquant) in each sector has to be consistent under the two tax regimes. The scale effects are different and so are the composition effects. For instance in the case of BIOSOL and SO_2-NO_2, the scale effect of the tax on BIOSOL is more than twice as large as the scale effect of the SO_2 or NO_2 tax, thus reversing the sign of the cross-price impact of a tax on the aggregate level of the other pollutants.

come substitutes for toxics and BIOWAT. This substitution is caused by a selective increase in pollution, mostly by way of a composition effect. The economy specialises in the goods that are cheaper to produce and that induce a sharp increase in the untaxed types of pollution.

In Table 11, the urban health impact of the coordinated reforms reflects these substitutions between broad groups of pollutants. Mortality due to air pollution increases dramatically under the combined scenarios involving toxics and some bio-accumulative 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 (via the dose-response functions discussed in Chapter 5). As shown in Table 12, damage reductions under coordinated reforms tend to be less substantial than under the environmental tax alone because of the substitution forces at work among pollutant types. There is one exception. The reform combining free trade and the tax on PART (PM-10) induces a sharper decrease in premature mortality because free trade allows substitution of natural gas for gasoline at a lower relative price than under the PART reform alone. Comparing coordinated reforms to the unilateral trade integration, all combined scenarios exhibit higher real income levels, inclusive of the health damages. The tax on PM-10 combined with unilateral trade integration induces net welfare gains, which are 16 per cent higher than the net gains under trade integration alone.

Although the coordinated unilateral trade and environmental policy reforms appear approximately additive in terms of changes in real GDP, trade, and consumption, not all scenarios lead to an environmental benefit, and here this additivity breaks down (as suggested by Table 12). This result is caused by substitution among emissions groups, which are exacerbated when trade distortions are removed. A tax on one pollutant group increases emissions of another pollutant group and associated health damages. The scenarios involving unilateral trade integration and a tax on BIOWAT, SO_2, NO_2, CO, VOC, and PART (PM-10) induce an environmental dividend. The other combined scenarios do not. All coordinated reforms pay for themselves in the narrow sense of the double dividend except the free trade *cum* BIOWAT tax reform, which leads to a negative GDP effect (see Table 9).

5. CONCLUSIONS

We analyse trade and environment linkages in the Chilean economy focusing on pollution emissions, their impact on urban public health, and natural resource based industries. When we consider 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 for Chile.

Table 11. Impact of combined trade and environmental policy reforms on health endpoints for Santiago (percentage)

	Combined NAFTA and Environmental Policy (25 Per Cent Reduction by Type of Effluent Emission)					
Scenario	*BIOAIR*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*
Premature mortality/100,000/year	-2.7	-15.4	-15.3	-11.2	-6.5	-23.1
Premature mortality/1 million males age 40-59	-10.8	-6.6	-6.5	-2.5	-5.9	-6.8
RHA/year	-1.3	-10.1	-10.0	-6.9	-9.6	-15.1
ERV/year	-3.2	-14.1	-14.0	-15.0	-6.3	-27.9
RAD/year	-3.2	-14.1	-14.0	-15.0	-6.3	-27.9
LRI/year (children < age 17)	-3.2	-14.1	-14.0	-15.0	-6.3	-27.9
Asthma attacks/year (asthmatics)	-0.4	-8.1	-8.1	-3.0	-11.1	-9.0
Respiratory symptoms/year	-2.0	-11.4	-11.4	-9.7	-8.4	-19.5
Chronic bronchitis/year	-3.2	-14.1	-14.0	-15.0	-6.3	-27.9
MRAD/year	0.4	-6.5	-6.5	0.3	-12.5	-3.8
Respiratory symptoms/year (children)	-1.6	-18.4	-18.3	-2.1	-7.1	-12.0
Chest discomfort episodes/year	-1.6	-18.4	-18.3	-2.1	-7.1	-12.0
Respiratory symptoms/year (adults)	-1.6	-20.5	-20.5	-2.2	-7.8	-13.3
Eye irritations/year (adults)	0.4	-6.5	-6.5	0.3	-12.5	-3.8
Headaches/year	-4.8	-4.9	-4.8	-27.6	-3.5	-35.9
IQ decrements	-10.8	-6.6	-6.5	-2.5	-5.9	-6.8
Cases of hypertension/1 million males age >20	-10.8	-6.6	-6.5	-2.5	-5.9	-6.8
Non-fatal heart attacks/1 million males age 40-59	-10.8	-6.6	-6.5	-2.5	-5.9	-6.8

Table 11. Extended

Scenario	*Free Trade and Aggregate Abatement of 25 Per Cent by Type of Effluent Emission (percentage)*												
	TOXAIR	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Premature mortality/ 100,000/year	9.7	7.7	10.6	11.8	-5.8	14.4	-12.6	-12.4	-5.9	2.5	-22.0	10.6	10.4
Premature mortality/ 1 million males age 40-59	-2.9	-3.7	-2.6	-8.2	-6.0	-0.2	-9.0	-8.8	-4.0	-7.0	-9.2	-2.5	-0.4
RHA/year	7.7	6.2	8.5	9.8	-2.8	11.6	-7.0	-6.9	-2.0	-3.8	-13.0	8.5	9.0
ERV/year	9.1	7.3	10.1	11.6	-10.8	14.3	-10.5	-10.3	-10.7	3.1	-27.4	10.2	8.5
RAD/year	9.1	7.3	10.1	11.6	-10.8	14.3	-10.5	-10.3	-10.7	3.1	-27.4	10.2	8.5
LRI/year (children < age 17)	9.1	7.3	10.1	11.6	-10.8	14.3	-10.5	-10.3	-10.7	3.1	-27.4	10.2	8.5
Asthma attacks/year (asthmatics)	7.1	5.6	7.7	8.9	1.0	10.4	-5.3	-5.2	2.1	-7.0	-6.2	7.7	9.2
Respiratory symptoms/year	8.2	6.6	9.0	10.4	-5.6	12.5	-8.2	-8.0	-5.0	-1.4	-18.0	9.1	8.8
Chronic bronchitis/year	9.1	7.3	10.1	11.6	-10.8	14.3	-10.5	-10.3	-10.7	3.1	-27.4	10.2	8.5
MRAD/year	6.6	5.2	7.0	8.2	4.2	9.3	-4.0	-3.8	5.6	-9.8	-0.4	7.0	9.4
Respiratory symptoms/ year (children)	11.1	8.7	11.7	12.2	6.0	14.9	-17.6	-17.3	5.2	1.1	-9.4	11.7	14.9
Chest discomfort episodes/year	11.1	8.7	11.7	12.2	6.0	14.9	-17.6	-17.3	5.2	1.1	-9.4	11.7	14.9
Respiratory symptoms/ year (adults)	12.6	10.0	13.4	13.4	6.8	16.3	-19.8	-19.6	5.7	1.2	-10.7	13.4	16.4
Eye irritations/year (adults)	6.6	5.2	7.0	8.2	4.2	9.3	-4.0	-3.8	5.6	-9.8	-0.4	7.0	9.4
Headaches/year	3.5	2.9	4.7	7.2	-29.1	9.5	1.4	1.6	-27.9	4.6	-36.2	4.7	-2.5
IQ decrements	-2.9	-3.7	-2.6	-8.2	-6.0	-0.2	-9.0	-8.8	-4.0	-7.0	-9.2	-2.5	-0.4
Cases of hypertension/ 1 million males age >20	-2.9	-3.7	-2.6	-8.2	-6.0	-0.2	-9.0	-8.8	-4.0	-7.0	-9.2	-2.5	-0.4
Non-fatal heart attacks/ 1 million males age 40-59	-2.9	-3.7	-2.6	-8.2	-6.0	-0.2	-9.0	-8.8	-4.0	-7.0	-9.2	-2.5	-0.4

Notes: Respiratory Hospital Admissions (RHA), Emergency Room Visits (ERV), Restricted Activity Days (RAD), Lower Respiratory Illness (LRI), Minor Restricted Activity Days (MRAD).

Table 12. Impact of combined trade and environmental policy reforms on health damages

	Combined NAFTA and Environmental Policy (25 Per Cent Reduction by Type of Effluent Emission)					
Scenario	*BIOAIR*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*
Health damages			*(million PPP$)*			
Mortality	-971.9	-1143.6	-1130.9	-648.5	-729.8	-1464.9
Morbidity	-70.2	-328.2	-327.1	-315.1	-191.3	-605.6
Total	-1042.2	-1471.7	-1458.0	-963.6	-921.1	-2070.5
% of GDP BAU (4)	-0.35	-0.49	-0.49	-0.32	-0.31	-0.69
Impact of reform on market allocation			*(percentage)*			
Real GDP change (5)	1.44	1.17	1.18	1.33	0.89	1.19
Total gains (5)-(4)	1.79	1.66	1.67	1.65	1.20	1.88

Table 12. Extended

	Free Trade and Aggregate Abatement of 25 Per Cent by Effluent Emission												
Scenario	*TOXAIR*	*TOXWAT*	*TOXSOL*	*BIOAIR*	*BIOWAT*	*BIOSOL*	*SO_2*	*NO_2*	*CO*	*VOC*	*PART*	*BOD*	*TSS*
Health damages						*(million PPP$)*							
Mortality	151.5	12.4	214.8	-190.1	-710.6	560.8	-1219.8	-1199.3	-559.3	-462.8	-1611.6	220.7	384.7
Morbidity	219.1	174.8	243.2	277.5	-210.7	341.9	-241.3	-237.1	-199.7	16.2	-580.1	244.5	220.4
Total	370.6	187.2	458.0	87.4	-921.3	902.8	-1461.0	-1436.4	-759.1	-446.6	-2191.7	465.2	605.0
% of GDP BAU (4)	0.12	0.06	0.15	0.03	-0.31	0.30	-0.49	-0.48	-0.25	-0.15	-0.74	0.16	0.20
Impact of reform on market allocation						*(percentage)*							
Real GDP change (5)	2.57	2.27	2.59	4.89	-7.09	4.50	4.48	4.49	4.75	4.17	4.50	2.59	4.85
Total gains (5)-(4)	2.44	2.21	2.44	4.86	-6.78	4.20	4.97	4.97	5.01	4.32	5.23	2.44	4.65

Trade integration scenarios offer different outcomes in terms of growth, international division of labour, and environmental consequences. Economic integration into NAFTA and MERCOSUR is relatively benign to the environment, and NAFTA integration has a small pollution elasticity with respect to the trade-induced growth. World trade integration via unilateral trade liberalisation, with no pollution abatement policy, induces higher growth and patterns of specialisation more adverse towards the environment, leading to detrimental impacts on public health in Santiago and considerable monetary damages associated with health deterioration.

Coordinated scenarios are well grounded in economic theory and represent the best of both worlds (efficiency gains from trade and protected environment). They are characterised 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, therefore increasing the dimensionality of policy coordination (e.g., trade policy, effluent taxes, natural resource management). This is a result specific to our investigation of Chile. By contrast, our investigation of Mexico suggests mostly complementarity between effluent types (see the summary in Chapter 10).

Another regularity shared by this country case study and the other ones included in this book is the relatively low cost of pollution abatement in terms of foregone aggregate income. In the 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 has to be qualified because the resource reallocation implied by the effluent taxes is substantial on a sectoral base 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, and 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.

NOTES

[1] See van der Mensbrugghe et al. 1998 and Beghin et al. 2001. The first study was initiated in 1996. The second study was initially conducted in 1997 but then was extensively updated in the summer of 2000 because a new pollution inventory became available for Santiago. We also accounted for decreased lead emissions due to new regulation in place in Chile. A few unit values used for the health valuation presented in Chapter 5 were updated as well because better information became available. Earlier and updated results produced similar stylised stories, however.

[2] According to Penn World Tables (Summers and Heston 1991), real income per capita grew 1.68 per cent annually from 1950 to 1973. In the decade following the crisis of 1973-75, the average real income per capita grew erratically, at the average rate of 1.53 per cent per year. Since 1985, real income per capita has been growing at 5.02 per cent a year. According to the International Monetary Fund's International Financial Statistics, real GDP grew at an annual rate of 7.68 per cent during the 1990s.

[3] For example, total suspended particulates and respirable particulates (PM-10), ozone, and carbon monoxide (CO) concentrations in Santiago are in excess of established standards for several months every year (The World Bank 1994). The one-year average concentration of PM-10 was estimated at 108.7 micrograms per cubic metre (µg/m3) in Santiago in 1992 and at 87.85µg/m3 in 1997.

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