ELSEVIER

Agricultural Economics 19 (1998) 87–97

AGRICULTURAL ECONOMICS

The interface between growth, trade, pollution and natural resource use in Chile: evidence from an economywide model[1]

Dominique van der Mensbrugghe[a], David Roland-Holst[a,b], Sébastien Dessus[a], John Beghin[a,c,*]

[a] OECD Development Centre 94 Rue Chardon-Lagache, 75016 Paris, France
[b] CEPR, London and Mills College, Oakland, California, USA
[c] Iowa State University, Ames, IA 510011-1070, USA

Abstract

We investigate the implications of trade liberalization and pollution taxes on aggregate income, pollution, and natural resource use in Chile with a neoclassical economywide model comprising 75 sectors. The model incorporates 13 measures of pollution effluents which are linked to the use of polluting inputs and energy use. We estimate the economic and environmental impact of Chile's participation in NAFTA, MERCOSUR, of unilateral trade liberalization and effluent taxes. Unilateral trade liberalization induces substantial worsening of pollution emissions and expansion of resource-based sectors, partly because of access to cheaper energy. NAFTA integration is environmentally benign in terms of pollution emissions.

1. Introduction

The interface between trade and environment linkages has become more evident in recent years due to recent trade negotiations such as the Uruguay Round and the NAFTA. There is an emerging consensus on the inadequacy of trade policy for environmental protection (Beghin et al., 1994). However, there is little quantification on environmental taxes, their interaction with trade policies and their economic and environmental impact (Low, 1992). For fast growing developing economies of the countries, 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 cost the strategy. Hence, it is essential to assess the environmental impact of trade liberalization, and how free trade eventually can be combined with pollution taxes to mitigate environmental degradation.

This paper presents new evidence on linkages between growth, trade, pollution and natural resource use in Chile. This empirical paper strengthens the basics of evidence for the rapidly evolving policy debate on trade-environment linkages (Beghin and Potier, 1997). Using a common modeling approach developed by the OECD Development Centre, we investigate the interactions between trade and environmental policies, focusing particularly on trade liberalization and coordinated policies of effluent

*Corresponding author. E-mail: beghin@econ.lastate.edu

[1] The views expressed in this paper should not be attributed to the OECD.

0169-5150/98/$19.00
PII S0169-5150(98)00047-4

taxation. We provided estimates of emissions for detailed pollution types at the national level. We identified various patterns of pollution intensities of aggregate production under outward orientation. Although we estimated increased intensities for several pollutants when trade liberalization is undertaken without concurrent environmental taxes, none of these is alarming.

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., 1990; World Bank, 1994). 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 growth (World Bank, 1994).

Next, we briefly describe our modeling approach, It is followed by a description of the policy reform scenarios considered for the simulations. Then, we present and discuss simulations results.

2. The TEQUILA model

The trade and environment equilibrium analysis (TEQUILA) model is a prototype computable general equilibrium model developed by the OECD development Centre for its sustainable development research programme. 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) with a careful disaggregation of natural resource based sectors and their forward linkages to manufacturing. 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 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 (labour, and capital (machinery and land)). Non-energy intermediate inputs are assumed to be used in fixed proportions with respect to total non-energy intermediate demand. The energy value added bundle is further decomposed into a labour aggregate and a capital energy bundle. Labour 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 three base fuel components. In this production structure, emissions are linked to intermediate consumption (inputs) rather than final output. Fig. 1 shows the nested structure of production.

Most existing CGE models investigating pollution issues assume fixed proportion between sectoral output and emission 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 estimate econometrically the pollution effluents by sector as being function of energy and input use (Dessus et al. (1994)). 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., 1991). 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 units of currency per unit of emission and are uniform taxes per unit of effluent for the 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. The intensities vary by sector and with relative prices since the use of 'dirty' inputs is influenced by relative price

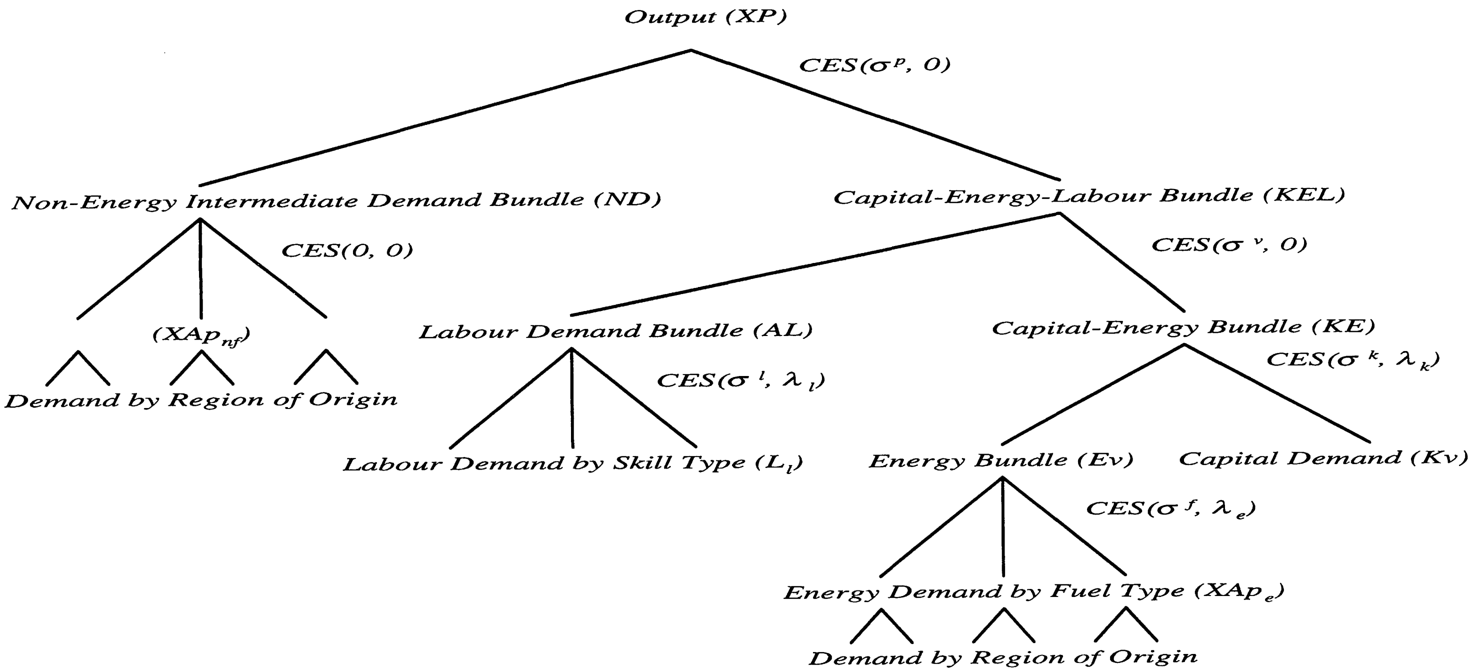

Fig. 1. (a) Each nest represents a different CES bundle. The first argument in the CES function represents the substitution of elasticity. The elasticity may take the value zero. Due to the putt/semi-putty specification, the nesting is replicated for each type of capital, i.e. old and new. The values 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 labour and energy, it is applied to all components. (b) 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. (c) The decomposition of the intermediate demand bundle, the labour 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 the components in the CES aggregation.

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 CO_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 adjustments reforms.

3. Policy reform scenarios

The time horizon of the simulations is the period 1991–2010. Every year, savings determine the pool of new investment for the next period and the model solves for an 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. Labor moves freely across sectors; existing capital is reallocated across sectors, but to a lesser extent due to partial mobility assumption built in 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 economic efficiency. We do not attempt to measure the cost of pollution and we characterize 'externalities' by the level of pollution emission implied by each scenario.

We first define a reference trajectory for the economy based on DRI–Macgraw-Hill prediction 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 1992–2010, 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 deviation (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 a time[2]. Each tax is such that the emissions of the targeted pollutant progressively decrease over time and reach a 25% decrease relative to its level in the BAU results by 2010. The phasing in of these taxes is set to obtain gradual reduction of 10% in 1995, 15% in 2000, 20% in 2005, and 25% 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 level (1992) as 90% of original tariffs in 1995, 60% in 2000, 30% in 2005, and no tariff in 2010. Terms-of-trade improvements are expressed as an increase in observed world prices for exports by 2% in 1995, 4% in 2000, 7% in 2005, and 10% 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

[2] Taxing all pollutants simultaneously raises difficulties. First, tracing the effect of any aingle 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.

allow us to consider these alternative trade integration 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 implication of coordinated trade and environment policies. Analytical results (Copeland, 1994; Beghin et al., 1997a) 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 that 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.

4. 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 sector which appear to be pollution hotspots in Chile. The following sectors exhibit high intensities and level for several effluent types: agriculture, sugar refining, mining, chemicals, metals, pottery, electricity, gas, and transportation sectors.

4.1. Effluent taxes

Effluent taxes have a small negative impact on growth except for the tax on (BIOWAT), which has a larger impact (8.1% 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% and investment decreases by 23%. Next we look at sectoral output effects. For the first four taxes (all three toxics, BIOAIR), fish and seafood output increase significantly (increases from 60 to 193%). For the same effluent taxes, mining activities decrease sharply (−17 to −60%). The tax on BIOWAT, which induces the largest decrease in aggregate output, has a negative effect on virtually all sectors, and it especially has strong effect on iron, coal, and basic metal (−30 to −59%).

Trade contracts with 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% for the taxes on toxic pollution; imports of wine and liquors increase by 120% with the tax on VOC. The same VOC tax has 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 bioaccumulative emissions, and NO_2, SO_2 and PART (PM-10). The larger subset of toxics and bioaccumulative emissions follows such a pattern. More intriguing is

Table 1
Impact of policy reform on aggregate variables

Aggregate variables	Environmental reform: aggregate abatement of 25% by type of effluent emission												
	TOXAIR	TOXWAT	TOXSOL	BIOAIR	BIOWAT	BIOSOL	SO_2	NO_2	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
Labour 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

Aggregate variables	Trade policy reform[a]			Combined NAFTA and environmental policy reform[b]					
	Lib2	NAFTA2	MERCOSU	BIOAIRN	SO_2n	NO_2n	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
Labour 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

Aggregate variables	Unilateral trade with aggregate abatement of 25% by type of effluent emission												
	TOXAIRl	TOXWATl	TOXSOLL	BIOAIRl	BIOWATl	BIOSOLl	SO_2l	NO_2l	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	13.6	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
Labour 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

[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 aggregated abatement of 25% by type of effluent emission.

the presence, in the aggregate, of substitution possibilities among effluents. For example, SO_2 and NO_2 are substitutes for TSS and for BIOAIR, BIOSOL.

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

Table 2
Impact of policy reforms on national effluent emissions

Effluent emissions	Aggregate abatement of 25% by type of effluent emission												
	TOXAIR	TOXWAT	TOXSOL	BIOAIR	BIOWAT	BIOSOL	SO_2	NO_2	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
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
SO_2	−6.0	−1.4	−0.5	−0.4	−5.2	0.2	−25.0	−25.0	−4.1	10.1	−25.3	−0.6	0.5
NO_2	−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	−9.0	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

Effluent emissions	Trade policy reform[a]		Combined NAFTA and environmental policy reform[b]						
	Lib2	NAFTA2	MERCOSUR	BIOAIRn	SO_2n	NO_2n	COn	VOCn	PARTn
TOXAIR	8.6	−1.0	3.5	−13.9	−3.0	−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
SO_2	19.9	3.1	1.6	3.4	−25.0	−25.0	−1.8	−8.4	−25.2
NO_2	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

National effluent emissions	Unilateral trade with aggregate abatement of 25% by type of effluent emission												
	TOXARIl	TOXWATl	TOXSOLl	BIOAIRl	BIOWAT	BIOSOL	NO_2l	NO_2l	COl	VOC	PARTl	BODl	TSSl
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
SO_2	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
NO_2	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	−24.0	−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

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 (1994) 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%). 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 limitations in 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).

4.2. *Trade integration*

We look at two types of trade integration leading to three scenarios: with the world (unilateral), and regional integration (NAFTA, and MERCOSUR). Unilateral liberalization induces the largest increase in GDP (+5.6%), followed by NAFTA (1.4%) and MERCOSUR (0.6%). 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 aggregated 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, would decrease. Hence, NAFTA integration departs significantly from world integration in terms of international specialization. MEROCOSUR 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 decrease 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 integration 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 unilateral reform, 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.

4.3. 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 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% 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 output, do not exceed 8.5%. A few individual rates increase sharply. For instance, the tax on TOXWAT emitted by nonmetallic minerals increases to 23.6%. As expected, the tax rates on VOC for wine and liquor and for furniture products increase further to 73 and 53%, 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% 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 BAIOAIR (lead) induces an expansion of fish, seafood and fruit, but 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, feedstuff, paper, petroleum refining, glass, nonmetallic minerals, and transportation decrease.

The pollution abatement figures, including the multiplier effects of the tax on pollutants which are not directly targeted by the tax, are surprisingly similar to the abatement figure 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 recurrent result in this type of simulation exercise (Lee and Roland-Holst, in press; Beghin et al., 1995; Beghin et al., 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% with trade liberalization and decreases by 14% with the tax on SO_2. Nonetheless, and combined reform (free trade + SO_2) induces an marginal increase in output of 1.4%! 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 tree 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 under the coordinated scenarios. For instance, imports of fish are larger under the combined scenario than under the tree 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 ones.

The inventory of emission tends to duplicate the patterns reached under single effluent tax reform, since we target the amount of pollution in a similar fashion (−25% 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 emission, but increase their activities under the four coordinated scenarios targeting SO_2, NO_2, PM-10 and CO_2. VOC emissions under most scenarios except the one which taxes VOC emissions.

5. Conclusions

We analyzed trade and environment linkages in the Chilean economy focusing on pollution emission and natural resource based industries. Trade integration 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 GAP). Unilateral trade liberalization, with no abatement policy, induces higher growth and pattern of specialization more adverse towards the environment. MERCOSUR simulations do not indicate substantial changes in income or pollution, except for increased emissions of bio-accumulative pollutants.

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, emission of untaxed pollutants increase considerably. 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; Beghin et al., 1997b).

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

Acknowledgements

The authors thank Brad Bowland, Gunnar Eskeland, and Raul O'Ryan for useful discussions.

References

Beghin, J., Potier, M., 1997. Effects of trade liberalisation on the environment in the manufacturing sector. World Economy 20(4), 435–456.

Beghin, J., Roland-Holst, D., van der Mensbrugghe, D., 1994. The trade environment nexus. Global Dimensions OECD. Econom. Stud. 23, 167–192.

Beghin, J., Roland-Holst, D., van der Mensbrugghe, D., 1995. Trade liberalisation and the environment in the Pacific basin: coordinated approaches to Mexican trade and environment policy. Am. J. Agric. Econom. 77, 778–785.

Beghin, J., Dessus, S., Roland-Holst, D., van der Mensbrugghe, D., 1996. Prototype CGE Model For The Trade and The Environment Programme, Technical Specification. OECD Development Centre Technical Paper No 116.

Beghin, J., Roland-Holst, D., van der Mensbrugghe, D., 1997a. Trade and pollution linkages: piecemeal reform and optimal intervention. Can. J. Econom. XXX, 442–455.

Beghin, J., Dessus, S., Roland-Holst, D., van der Mensbrugghe, D., 1997b. The impact of free trade and pollution taxes on Mexican agriculture: a general equilibrium analysis. Agric. Econom. 17, 115–131.

Copeland, B.R., 1994. International and the Environment: policy reform in a polluted small open economy. J. Environmental Econom. Manag. 20, 44–65.

Copeland, B.R., Taylor, M.S., 1994. North–south trade and the environment. Quart. J. Econom. 109, 755–787.

Dessus, S., Roland-Holst, D., van der Mensbrugghe, D., 1994. Input-based Estimates for Environmental Assessment in Developing Countries. OECD Development Centre Technical Paper No., Paris, August 1994.

Lee, H., Roland-Holst, D., The environment and welfare implications of trade and tax policy. J. Dev. Econ., in press.

Low, P. (Ed.), 1992. International Trade and the Environment. World Bank Discussion Paper No. 159, Washington, DC, .

Martin, P., Wheeler, D., Hettige, M., Stengren, R., 1991. The industrial pollution projection system: concept, initial development, and critical assessment. mimeo, The World Bank.

Papageorgiou, D., Choski, A.M., Michaey, M., 1990. Liberalizing foreign trade in developing countries. The Lessons of Experience. World Bank Publications, Washington, DC.

World Bank, 1994. Chile: Managing Environmental Problems. Economic Analysis of Selected Issues, Report No. 13061-CH, Washington, DC.