International Trade and the Environment: Evidence from the North America Free Trade Agreement (NAFTA) [1]

by

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Abstract

This paper analyze the linkages between international trade/investment liberalization and the environment. Specifically, the paper examines the hazardous waste (HW) generation in the Mexican, the Californian and the Rest of the U.S. economy, under the North-American Free Trade Agreement (NAFTA). The investigation uses a multiple country computable general equilibrium (CGE) model to forecast the future change in quantity and composition of hazardous waste (HW) generation under NAFTA. The CGE model constructed allow us to use the HW results for capacity assurance treatment planning of HW management in Mexico and California. It is shown that country sectoral pollution intensity coefficients estimation are crucial to estimate accurately pollution under a free trade framework.

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1. INTRODUCTION

The literature relating economic activities to the environment and natural resource systems is growing. One of the main problems that researchers face is the lack of reliable environmental data, which makes reliable research a lengthy, if not unattainable, task. On the other hand, environmental degradation is increasing in today's world. Air pollution, hazardous waste (HW) and soil contamination are continuously increasing leading to soil erosion, water pollution, acid rain, and deforestation-among other problems. Public fears of irreparable damage to the planet threatening the sustainable development of the planet have put severe pressure on government and international agencies to address environmental problems. Because of public pressure and the serious environmental problems caused by liberal policies including free-trade, governments have begun to introduce environmental regulations and policies. Such policies include binational and multilateral agreements, which have been designed to handle pollution and improve technical cooperation among nations.

Multilateral negotiations, such as the Uruguay Round and the North America Free Trade Agreement (NAFTA), have increased the public's awareness about the relationship between free-trade and the environment.[2] Thus, the linkage between international trade and the environment has generated widespread interest, concern and controversy[3] which lately have been widely debated. However, the lack of adequate quantitative studies, especially empirical studies for environmental policy analysis, makes it very difficult to address environmental policies and define the role that institutions could play in this field, especially in the definition of standards and international property rights (Muñoz, 1994).

NAFTA and its accompanying North American Agreement on Environmental Cooperation (NAAEC) and the institution for providing technical support on environmental issues under NAFTA, the Commission for Environmental Cooperation (CEC), had huge hopes for the improvement of the environment, especially in the US-Mexico border area. Today, four years after NAFTA has been in place, these hopes are still in the process of being realized.[4]

NAFTA has facilitated new investment flows and trade between Mexico and the U.S.. Unfortunately, NAFTA has resulted in increased soil, air and water pollution, especially in the U.S.-Mexico border (Ganster, 1996). Moreover, the industrial development and diversification of economic activities along the U.S.-Mexico border have resulted in widespread environmental hazardous waste (HW) contamination (Perry et al., 1990). The lack of proper management and capacity for handling HW along the U.S.-Mexico border, poses a serious and long-term human health and environmental risks in the region. Industrial restructuring and location decisions of industry in response to trade liberalization under NAFTA, could influence the quantities and types of HW generated. Planning for adequate HW treatment and disposal capacity for California and Mexico in a binational context is a difficult task. Adequate methodologies for linking international trade with changes in sectoral production and changes in hazardous waste generation have not yet been developed. Only with such methodology, capacity assurance treatment planning can be developed. This research attempts to address this problem.

While some studies deal with the topic of international trade and its impact on the environment as result of NAFTA (Grossman and Krueger, 1993; Beghin, Dessus, Roland-Holst and van der Mensbrugghe, 1996). The current research is one of the few empirical studies which analyzes NAFTA and environmental linkages, especially in respect to HW, in both the Mexican and Californian economies. In sum, the lack of proper binational management of HW policy in the NAFTA context, could be partially attributed to the lack of studies in environmental policy modeling.

The technical facts for modeling HW under free trade can be divided into some general characteristics of HW as pollution and the specific actual situation of HW pollution in the U.S.-

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[2] For recent survey of this literature, see Beghin, Roland-Holst and van der Mensbrugghe (1994), Snape (1994) and Low (1992).

[3] See Low(1992) for a survey about this debate.

[4] For further details see CEC (1996) and Mumme and Duncan (1996).

Mexico context. The general characteristics of HW pollution can be summarized as follows: (i) HW pollution presents one of the most serious threats to human health, as compared to other types of pollution (e.g. air). HW potential health issues are grave including cancer and reproductive effects; (ii) HW pollution presents a very high threat to natural resources, particularly for water. Elimination of HW in water through remediation is very costly and sometimes unfeasible at any cost; (iii) HW prevention is much cheaper than HW remediation; (iv) in most cases, human exposure to HW is difficult to be detected (e.g., VOCs in water and PCBs in ground). This is a major difference in this type of pollution as compared to other forms of pollution such as air pollution which is easily detectable; and finally (v) HW pollution management is very technical and requires well-trained personnel, which in many cases is not available.

With respect to some specific facts of HW under NAFTA, the following should be noted: (i) there is a clear disparity in HW regulation and in enforcement/control practices between the U.S. and Mexico[5]. This disparities could act as an incentive for HW polluting industries migration south of the border; (ii) there is a large difference between the U.S. and Mexican HW infrastructure, trained personnel, and management capacity. In the U.S., most of the HW generated is treated. On the other hand, only 10% of Mexican HW generated is treated. This low level of treatment capacity is a serious threat to human and natural resources in Mexico; (iii) there is a HW movement across the border, (iv) there is an obvious difference on the HW classifications between the U.S. and Mexico, which could be an incentive for free-riding activities of HW movement across the border; and finally (v) in Mexico, most of the HW is poured into the sewage system and as a result, HW pollution is a serious threat for the Mexicans and the US-Mexico border region sustainable development program,[6] especially under NAFTA.

Thus, in order to assess the HW problem under free-trade and design some policies to manage this problem in a binational context, it is important to develop quantitative studies, such as the present one, with the purpose of defining priorities with respect to environmental policies.

The remaining of this paper is organized as follows: Section 2 provides a brief review about literature on international trade and the environment. Section 3 provides an explanation of the equations considered in the environmental computable general equilibrium model (CGE). Section 4 contains an explanation of the economic and environmental data base used to calibrate the environmental CGE model. Section 5 contains the model simulation results. Section 6 contains conclusions and policy recommendations emanating from this research.

2. PREVIOUS LITERATURE ON TRADE AND THE ENVIRONMENT

There are few quantitative empirical studies which analyze the linkage between international trade and the environment. The following are among the more important works in existence.

Lucas, Wheeler, and Hettige (1992) conducted an empirical multiple country regression study to analyze the connection between toxic emissions and trade policy liberalization. Due to the lack of data, they estimate the pollution intensity coefficients (ICs) using the U.S. Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI) database. The ICs were determined (lb/GDP), for the U.S. and extrapolated to the rest of the countries.[7] The study contains two parts. The goal of the first part, is to see whether high income countries have lower pollution intensity coefficients. In this part, the authors analyze the relation between the manufacturing sector's intensity coefficients and the country's income per capita. Two conclusions are obtained in the first part of this study. First, the toxic intensity coefficients in the manufacturing sector of

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[5] For further details, see Madrid (1997).

[6] Most of the volatile organic chemicals (VOCs) known have been detected in border rivers (see Perry et al.,1990).

[7] For more details about the limitations and problems of using the TRI database and extrapolating its coefficients, see Madrid (1997).

high income countries are not lower. The toxic intensity of GDP declines only because the manufacturing share in GDP declines beyond a certain level of income. Second, the growth in toxic intensity has been far more rapid in less developed countries (LDCs) than in developed countries (DCs). In the second part of this study, the authors try to find the relation between the growth rate of the manufacturing intensity coefficient and trade openness through time (1960-1980). The conclusions are that there were no major changes in ICs in the 1960s. In the 1970s and 1980s, the rapidly growing closed economies experienced very rapid growth in their ICs. In contrast, the rapidly growing open economies had essentially toxic-neutral structural change in the 1970s and a strong shift toward less toxic structure in the 1980s. These results should be taken with caution because the regressions correlation factors (R-squared) obtained in this study are on average very low (0.2). Moreover, the ICs used in that study were estimated from the TRI database and extrapolated to LDCs.[8]

Birdsall and Wheeler (1992), conducted a cross-country study to find the relationship between the toxicity ICs and three economic variables: per-capita income, growth of per capita income, and the degree of openness. The sample used corresponds to 25 Latin American countries and the data corresponds to the U.S. EPA TRI database. The main conclusion of this study is that over the last two decades, the more open economies have ended up with a cleaner set of industries.

Grossman and Krueger (1993) is the only empirical study that analyses the effect of NAFTA on the change of toxic wastes in particular sectors and industries of the U.S. and Mexico. This study uses the Brown, Deardorff, and Stern (1992) CGE model of Canada, U.S. and Mexico to estimate the expansion or contractions of the different economic sectors that would occur post-NAFTA. Two different scenarios were used to predict how the sectoral output would affect the toxic releases. The U.S. EPA's Toxic Releases Inventory (TRI) for 1989, was the data used to estimate the intensity coefficients for the U.S. and Mexico. They found that trade liberalization with increased investment in Mexico, causes changes in the scale and composition of output that lead to an increase in toxic releases in the U.S. and Mexico. The study surprisingly estimated that the trade liberalization (without investment liberalization) would decrease pollution in Mexico. This was because of the effect of trade on the product mix (in favor of labor and less pollution intensive industries for Mexico). On the other hand, trade/investment liberalization would increase pollution considerably in Mexico. However, the Grossman and Krueger study estimates toxic pollution intensity coefficients for Mexico using the US TRI database.

In this paper previous research shortcomings are addressed in the sense that databases and pollution ICs are not extrapolated. Additionally, in this paper a complete different approach is taken, in the sense that emissions are disaggregated by type of HW pollutants which are directly linked to different types of HW treatment. Thus, this new approach allows for the design of a "capacity assurance plan for HW management" on a binational basis under a free trade scenario.

3. ENVIRONMENTAL MODEL

In this section the most salient features of the environmental CGE model are described. Model equations can be found in the Appendix. The environmental CGE model follows the standard theoretical specification of trade-focused CGE models[9] and it was implemented using GAMS software.[10]

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[8] Empirical evidence from this research shows that ICs can vary by a factor of three from one region to another inside the United States. Therefore, extrapolation of ICs from region to region is not recommended, especially from DCs to LDCs.

[9] See Robinson (1989) and Devarajan, Lewis, and Robinson (1990) for a survey of trade-focused CGE models.

[10] For further details about GAMS programming, see Brooke, Kendrick and Meeraus (1988).

This environmental CGE is an extension of the NAFTA CGE framework developed by Robinson, Burfisher, Hinojosa and Thierfelder (1992) (RBHT model)[11]. The environmental CGE is a static multiple country model. Four regions are considered, Mexico, California, Rest of the US (ROUS), and the rest of the world (ROW). The model has 11 economic sectors. Each region or economy has six factors of production (four types of labor, capital and land). Output-supply and input-demand equations are specified for each economy.

The quantity equations can be described as follows. At the top production level, the sectoral output is produced according to real-value added CES production function in primary factors and fixed input-output coefficients for intermediate inputs demand. Both are aggregated in a Leontief way to obtain the composite production or output (equation 1). Producers are assumed to maximize profits, implying that each factor (capital, labor and land) is demanded so that the marginal product or revenue equals the marginal cost (equation 2). In each economy, factors are not assumed to receive a uniform wage or "rental" (in the case of capital) across sectors. Instead, a "factor market distortion" variable (*WFDIST*) is imposed, which fixes the ratio of the sectoral return to a factor relative to the economy wide average return rate for that factor. This distortion factor is considered because in the real world, factor prices (wages and rental) are not uniform across economic sectors. Hence, this adjustment factor can adjust economy-wide average wage rate and capital return rate to be sector specific. In sum, the incorporation of this variable, allows one to measure the degree to which a given economic sector's marginal revenue product deviates from the average. Since, in the model pollution is directly linked with changes in economic activity, the inclusion of this distortion factor increases the accuracy of resource allocation and changes of production structure under free-trade; consequently, the pollution results are more accurate. Finally, intermediate input demand is given by fixed input-output coefficients (equation 3).

Exports are modeled as follows: Each sector produces a composite commodity that can be transformed according to a constant elasticity of transformation (CET) function into a commodity sold on the domestic market (*D*) or for export (*E*). The CGE model assumes that the productive sectors produce both tradable goods for the export market (E), and non-tradable goods for the domestic market (*D*). In standard analytic models, it is often assumed that domestic and foreign goods are perfect substitutes for each other, i.e. that all goods are tradable. In applied models, however, this unrealistic assumption can be relaxed. Assuming that *D* and *E* are perfect substitutes, leads to the situation where there is complete sectoral specialization in a few set of goods, and no domestic production in the majority of the economic sectors. The present model assumes that *E* and *D* are imperfect substitutes for each other, making the model more realistic. The CET export supply functions require elasticities of transformation between goods sold in the domestic markets and in the export markets.

Normal practice in CGE modeling is to use a CES function for the import aggregation demand equations. However, this leads to empirical problems due to the restrictive nature of the CES functions, which does not allow non-unitary expenditure elasticities. In a multiple country CGE model, the assumption of fixed share parameters as result of using a CES, determines the volume and direction of world trade with price changes affecting shares only marginally (Robinson, Soule and Weyerbrock, 1991). Also, CES constrains the income elasticity of demand for imports to unity in every sector. Thus, with all income elasticities equal to one, the model cannot handle major expansion of trade. To avoid these empirical problems that stem from a constant elasticity of substitution (CES), this environmental CGE model employs the Almost Ideal Demand System

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[11] The environmental CGE, presented in this research differs from the RBHT model in different ways. First, the RBHT model was developed to evaluate economic effects of NAFTA, without considering environmental variables. In the present model HW environmental variables were included. Second, the environmental CGE considers California as a separate region from the rest of the US.

(AIDS)[12] to describe the import demand functions. AIDS is a flexible functional form which allows non-unitary expenditure elasticity. The major advantage of the AIDS approach is that it includes an income effect which is empirically important. It allows the model to generate trade creation, permitting trade to grow more rapidly than aggregate GDP without major changes in relative prices. Thus, the AIDS specification generates more realistic volume and terms of trade effects. In sum, the relative demand for imports (*M*) and domestic goods (*D*) is assumed by an Almost Ideal Demand System (AIDS), which depends on their relative prices, domestic and import prices (P^m, P^d), by way of estimated expenditure and substitution elasticities for each sector in each country.

Each region traces a circular flow of income from producers through factor payments, to households, government, and investors, and finally back to the demand for goods in product markets. The government collects the official tariff revenue, and the equivalent tariffs of nontariff barriers are collected by private parties.

The model has three different trade-productivity externality links or parameters. These externalities capture the sectoral and/or country pattern of industrialization, economies of scale, and total factor of productivity (TFP) change over time. From empirical evidence, in particular from those studies by OECD, NBER, and World Bank,[13] several ways of modeling these facts have emerged.[14] The consideration of these type of endogenous productivity links in the CGE models, have expanded the traditional neoclassical approach to a more endogenous approach. Both theoretical work (Romer, 1986, 1989) and empirical work support this approach.

The first parameter (*SAD*), denominated as an export productivity externality parameter (equation 47), is associated with sectoral export performance in which higher sectoral export growth generates an increase in domestic productivity in that sector. This externality represents the total sectoral exports momentum. In other words the, faster the sectoral exports the higher the productivity. The second parameter (*SAD2*), denominated as intermediate input productivity parameter, is associated with an increase in production of intermediate and capital goods, which depends on the share of intermediate inputs in production. The third externality (*SAC*) denominated as capital good productivity, corresponds to the externality parameter associated with the country's aggregate exports such that increased exports make physical capital (stock of capital in machinery and other physical capital) more productive-an effect which is embodied in capital stock input that helps the production process. Therefore, increasing total aggregate exports yields a higher value of this parameter. The elasticity value considered for the export productivity externality (*etae2*) is consistent with empirical estimations. For the ROUS and California, value of 0.1 was considered only for the manufacturing sector. For the rest of the economic sectors, this value is considered equal to zero. In Mexico, this elasticity was considered equal to zero for five sectors, which does not present any productivity increase historically (corn, other program crops, fruit and vegetables, other agriculture and services). Elasticities values for the other Mexican sectors varies between 0.08 and 0.1. The intermediate input productivity externality elasticity (*etam2*) was considered equal to 0.5 for all regions. The capital goods productivity externality parameter elasticity (*etak2*) was considered equal to 0.5 for all regions.

The government deficit, aggregate investment and savings, and the balance of trade are the three macro balances of the model. The government deficit is the difference between revenue and

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[12] The AIDS specification in this model draws heavily on work done by Robinson, Soule and Weyerbrock (1991). They analyze the empirical properties of different import aggregation functions in a three-country model of the U.S., European Community and the Rest of the World.

[13] See comparative studies by Balassa and Associates (1982), Bhagwati (1988), Chenery, Robinson, and Syrquin (1986). For correlation between export growth and aggregate growth are presented in Heller and Porter (1978), Balassa (1978), Feeder (1983) and Jung and Marshall (1985).

[14] See, Devarajan, Lewis, and Robinson (1996) (Chapter 7-Productivity and Externalities: Models of Export-Led Growth) for an detailed explanation of modeling trade externalities linkages.

spending, where real spending is fixed exogenously, but revenue depends on a variety of taxes. Hence, the government deficit is determined endogenously. Real investment is set exogenously, while savings is determined residually to achieve the nominal saving-investment balance.[15]

Pollution is modeled as follows: every sector has a fixed sectoral intensity coefficient characterized by the relationship between the HW generated (in tons) and the quantity of output generated in that sector (in US$). The pollution intensity coefficients vary across sectors and regions. The total sectoral pollution is given by the fixed sectoral coefficient times sectoral output (equation 56). The sectoral pollution is disaggregated by type of pollutant, which is the result of the pollutant share coefficient times the total sectoral pollution (equation 57). The pollutant sectoral share coefficients were estimated for California using the RCRA-HW Report (GM Form database). The California sectoral share coefficients are extrapolated to Mexico. Finally, the sectoral demand for treatment is estimated as the pollutant treatment coefficient times the sectoral quantity by type of pollutant (equation 58).

4. ECONOMIC AND ENVIRONMENTAL DATABASE

4.1 Economic Database

Table 1 shows the aggregated economic data of the three regions considered in the model. This data is used to generate the benchmark or base solution of the environmental model. The data shows that the gap between California and the Rest of U.S. (ROUS) compared with Mexico is very wide. California has less than half of the Mexican population, but its GDP is three times as large as Mexico's GDP.

TABLE 1
Model Comparative Aggregate Data (Base Year- 1990)

	CALIFORNIA	MEXICO	REST OF THE US
Aggregated Indicators			
GDP (Billions of U.S. Dollars)	612.7	175.0	3858.4
Labor (Millions)	13.6	26.4	94.3
Trade Flow (as % of GDP)			
Total Exports	40.3	16.5	13.6
Total Imports	43.2	13.2	16.8
Employment Structure (% of total)			
Rural Labor Force	1.6	13.1	1.1
Urban Unskilled Labor Force	16.8	23.9	17.8
Urban Skilled Labor Force	48.4	38.0	48.5
White Collar Workers	33.2	25.0	32.6

Source: World Development Report 1990, 1991 and from U.S. and Mexican Social Accounting Matrices developed by the Economic Research Service, U.S. Department of Agriculture (USDA/ERS).

Note: In trade flows is considered trade among the regions (e.g. California total exports considers exports to Mexico, the rest of U.S. and the rest of the world).

Table 2 shows the intra and international trade flows among the regions considered in the model. Mexico, has a higher international trade exports/GDP share (16.5%) than the rest of the U.S. (8.5%) and California (4.3%). Mexico also has a slightly higher share on international imports than the U.S. and California. In other words, Mexico is much more dependent on exports than the U.S. In particular, the U.S. accounts for 67% of Mexico's imports. On the other hand, California is highly dependent on the ROUS trade. California imports from the ROUS accounts for 32.2 % of its GDP.

TABLE 2
Total Regional Exports and Imports as Percentage of GDP (Base Year)

Exporters:	Trading Partners	Total Trade	International Trade*

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[15] Enterprise savings rates for each region are assumed to adjust to achieve the necessary level of aggregate savings in each country. This is known as "Johansen" macro closure.

	CA	US	MX	ROW		
CA	0.0%	36.0%	0.3%	4.0%	40.3%	4.3%
MX	1.4%	8.8%	0.0%	6.3%	16.5%	16.5%
ROUS	5.1%	0.0%	0.4%	8.1%	13.6%	8.5%

Importers:	Trading Partners				Total Trade	International Trade*
	CA	US	MX	ROW		
CA	0.0%	32.2%	0.4%	10.6%	43.2%	11.0%
MX	1.0%	8.8%	0.0%	3.4%	13.2%	13.2%
ROUS	5.7%	0.0%	0.4%	10.7%	16.8%	11.1%

Source: World Development Report 1990 and 1991. From U.S. and Mexican Social Accounting Matrices developed by the Economic Research Service, U.S. Department of Agriculture (USDA/ERS).
*** Note**: International trade does not consider intra-trade between CA and the Rest of the U.S..

Table 3 shows the sectoral structure of GDP and bilateral import and export flows as percentages of total GDP. Note that the ROUS and California economies are more service oriented (77.7% and 77.4%) than the Mexican economy (63.3%). On the other hand, Mexico's agriculture accounts for 8.0% of its total GDP, whereas California's agriculture accounts for only 1.7% of its total GDP. With respect to exports, California's principal exports to Mexico are capital goods, whereas, Mexico's main exports to the U.S. and California are basically oil and consumer durables

TABLE 3
GDP and Bilateral Export and Import Flows-Base Year (in percent)

Sector	Country Shares (Percent)											
	GDP (%)			U.S. Exports (%)			CA Exports (%)			MX Exports (%)		
	US	CA	MX	CA	MX	RW	US	MX	RW	US	CA	RW
Corn/feedgrain	0.0	0.0	0.7	0.0	1.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Other program crop	0.6	0.1	1.1	0.6	3.7	3.4	0.5	0.3	1.1	0.0	0.0	0.3
Fruit & Vegetables	0.1	1.0	1.1	0.3	0.0	0.1	1.9	1.1	4.0	3.0	3.1	3.0
Other agriculture	0.8	0.6	5.1	2.5	1.6	0.2	2.5	0.4	1.4	4.9	4.9	2.0
Food processing	1.5	2.4	6.2	13.6	5.5	2.3	7.5	3.3	8.0	2.8	2.8	4.9
Light manufacture.	4.7	3.3	5.5	18.0	3.4	7.3	6.2	14.5	4.5	7.5	7.6	3.7
Oil, gas, mining	2.3	1.2	2.9	3.4	3.9	2.3	1.7	21.5	5.3	16.7	16.0	0.0
Intermediate inputs	6.0	2.9	8.2	19.9	14.4	14.1	10.9	21.2	10.9	15.8	15.9	6.7
Consumer durables	1.8	2.1	2.5	0.2	12.4	10.4	4.6	4.5	4.0	17.5	17.6	20.6
Capital goods	4.5	9.0	3.4	18.5	21.3	30.1	17.8	32.8	59.4	12.8	12.9	10.6
Services	77.7	77.4	63.3	18.9	32.5	29.5	46.4	0.4	1.5	19.1	19.2	48.2
Total	100	100	100	100	100	100	100	100	100	100	100	100

Source: From U.S. and Mexican Social Accounting matrices developed by the Economic Research Service, U.S. Department of Agriculture (USDA/ERS).
Notes: Other programs crops sector includes food grains, potatoes, tobacco, and cotton.

Table 4 shows the average protection rates by sector and region considered in the model. Note that despite the huge trade volume between Mexico and the U.S., there is still a huge number of import barriers such as tariffs and non-tariff barriers. In general, the U.S. economy is much less protected than the Mexican economy. California and ROUS have an average import tariff of 2.6%, whereas Mexico has an average import tariff of 7.9%. In general, the highest rate of protection can be found in agriculture. Manufacturing and food sectors are highly protected in both countries. On the other hand, Mexico has higher rates of protection on capital good imports from the U.S. (12.7 %).

TABLE 4

Average Sectoral International Trade Protection Rates (Percentage)

	Tariffs on Imports to U.S. from:			Tariffs on Imports to MX from:		Tariffs on Imports to CA from:		
Economic Sector	CA	MX	ROW	ROUS/CA	ROW	US	MX	ROW
Corn/feedgrain	0.0	18.0	11.9	45.0	45.0	0.0	18.0	11.9
Other program crops	0.0	0.7	1.5	12.9	14.2	0.0	0.7	1.5
Fruits and Vegetables	0.0	10.5	3.1	12.5	11.9	0.0	10.5	3.1
Other agriculture	0.0	8.4	9.2	8.9	11.6	0.0	8.4	9.2
Food processing	0.0	10.8	27.9	8.2	12.8	0.0	10.8	27.0
Light manufacturing	0.0	7.1	13.7	8.1	10.1	0.0	7.1	13.7
Oil, gas and mining	0.0	0.5	1.2	8.8	8.3	0.0	0.5	1.2
Intermediates	0.0	1.7	11	8	8.8	0.0	1.7	11
Consumer durables	0.0	2.4	2.3	12	10.0	0.0	2.4	2.3
Capital goods	0.0	2.4	2.4	12.7	11.6	0.0	2.4	2.4
Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	0.0	2.6	5.7	7.9	10.0	0.0	2.6	5.7

Source: From U.S. and Mexican SAMs developed by the Economic Research Service, U.S. Department of Agriculture (USDA/ERS). CA and the ROUS tariff from U.S. Department of Commerce; CA and the ROUS non-tariff barriers from the U.S. Department of Agriculture. For Mexico: World Bank Country Report.
Note: Tariffs figures include both tariffs and non-tariff barriers (NTBs) on trade among the regions. Average is weighted by trade flows.

The model's economic data base consists of social accounting matrices (SAMs) for each region, including data on trade flows among regions. The model has been calibrated using the benchmark technique based on 1990 data.

4.2 The Environmental Database

4.2.1 HW Pollution Intensity Coefficients

California HW pollution intensity coefficients were estimated using the RCRA-EPA Biennial Hazardous Waste Report (BHWR)[16], 1991. Large quantity[17] HW generators are required to report HW generation to the EPA.

The BHWR generators manifest (GM Form) database was corrected by converting the different weight and volume measurement units (short tons, kilos, pounds, gallons and liters) to a constant weight measurement (tons). Then, the off-site shipments were corrected and verified with the manifest summary database. The BHWR database was aggregated into the eleven sectors of the model and the intensity coefficients where estimated for the eleven economic sectors. For the ROUS, only the total HW quantity generated was known and therefore the sectoral intensity coefficients were estimated by extrapolating the California ICs and correcting them by the ratio of the quantities generated in California and the ROUS.

Table 5 contains aggregated HW pollution in tons and HW pollution ICs. Results show that the Mexican database could be understating the generation of HW since it is difficult to explain why Mexico has a lower aggregated HW pollution ICs than the U.S. as a whole. The discrepancies between the aggregated U.S. and Mexican HW intensity coefficients could be the result of different

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[16] The BHWR report is biennially. It contains the quantity of HW generated, the SIC code of the economic activity, the type of pollutant defined by an EPA code, and type of treatment.

[17] Large quantity HW generators are defined as a generation in any single month of 1,000 kilos or more of HW as defined by the Resource Conservation Recovery Act (RCRA) of 1976.

Mexican HW and EPA-RCRA classifications[18] standards, as well as the different productive structure of these countries.

TABLE 5
Basic Indicators and Aggregated HW Pollution Intensity Coefficients (Base)

Indicators	MX	CA	ROUS	US as a whole
GDP (Billions of US$)	175.0	512.7	3858.4	4471.1
Labor Force (Thousands)	26,443	13,600	94,310	107,910
Total Waste Generated (Thousand Tons)	8,000	12,963	263,091	276,055
Output Intensity Coefficient (Ton/Million US$)	0.0457	0.0212	0.0682	0.0617
Labor Intensity Coefficient (Ton/Worker)	0.302	0.953	2.790	2.558

Source: U.S. EPA Biennial Hazardous Waste Report, 1989 and 1991. SEMARNAP, "Programa para Minimización y Manejo Integral de Residuos Industriales Peligrosos en Mexico", 1996, and authors' estimations.

Table 6 shows the sectoral ICs for the regions considered in the model. California's low ICs with respect to the ROUS can be explained by the demanding California HW norms and programs with respect to HW reduction and minimization. California actively supports waste minimization and has encouraged a variety of waste minimization activities. It also maintains many programs to support and promote technologies for waste minimization, including a grant program, waste auditing and information sharing activities. The most significant waste minimization program set by California, in terms of its effect on current state capacity needs, is for incinerable wastes (HWMCAP, EPA,1992). Note that California can be considered one of world's leader in HW reduction program and applications of new technologies for HW treatment.

The Mexico pollution ICs were calculated using the Mexican HW pollution database obtained from the Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP), the official Mexican entity that handles environmental matters in Mexico in conjunction with this research. It is also important to mention that this pollution database should be used with caution, since this is the first Mexican official HW pollution report. In addition, HW pollution has been avoided in Mexican economic, political and technical discussions due to reliable data.

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[18] In the U.S. under the RCRA, 850 wastes are classified as hazardous. On the other hand, in Mexico, the norm NOM-CRP-001-ECOL/193 (previous denominated as NOM-052-ECOL93) considers only 471 wastes as hazardous.

TABLE 6: Sectoral HW Generation and Pollution Intensity Coefficients

	REST OF THE U.S.					CALIFORNIA					MEXICO				
Sector	Real GDP		HW Pollution		Intensity Coeff.	Real GDP		HW Pollution		Intensity Coeff.	Real GDP		HW Pollution		Intensity Coeff.
	(Billion $)	(Percent)	(Tons)	(Percent)		(Billion $)	(Percent)	(Tons)	(Percent)		(Billion$)	(Percent)	(Tons)	(Percent)	
Corn/Feedgrains	1.35	0.03%	0	0.00%	0.00000	0.011		0	0.00%	0.00000	1.251	0.71%	0	0.00%	0.00000
Program Crops	21.85	0.57%	0	0.00%	0.00000	0.56	0.09%	0	0.00%	0.00000	2.021	1.15%	0	0.00%	0.00000
Fruits & Vegestable	4.168	0.11%	0	0.00%	0.00000	6.443	1.05%	0	0.00%	0.00000	1.94	1.11%	0	0.00%	0.00000
Other Agricuture	29.777	0.77%	2,238	0.00%	0.00008	3.661	0.60%	114	0.00%	0.00003	8.98	5.12%	0	0.00%	0.00000
Food Processing	58.199	1.51%	46,003	0.02%	0.00079	14.803	2.42%	4,778	0.04%	0.00032	10.985	6.27%	480,000	6.00%	0.04370
Light Manufacturing	180.057	4.67%	1,113,157	0.42%	0.00618	20.323	3.32%	51,002	0.39%	0.00251	9.695	5.53%	997,000	12.46%	0.10284
Paper								1,977	0.02%		1.636	0.93%	320,000	4.00%	0.19560
Textiles								5,699	0.04%		2.794	1.59%	320,000	4.00%	0.11453
Oil, Gas, Mining	90.698	2.35%	61,428,721	23.35%	0.67729	7.595	1.24%	2,070,772	15.97%	0.27265	5.128	2.93%	1,520,000	19.00%	0.29641
Intermediate Goods	230.617	5.98%	148,303,921	56.37%	0.64307	17.988	2.93%	4,688,672	36.17%	0.26066	14.5	8.27%	4,100,000	51.25%	0.28276
Primary Metals								611,469	4.72%		1.997	1.14%	800,000	10.00%	0.40060
Fabricated Metals								3,292,752	25.40%				800,000	10.00%	
Chemicals								757,835	5.85%		5.829	3.33%	2,320,000	29.00%	0.39801
Consumer Durables	69.719	1.81%	88,878	0.03%	0.00127	12.598	2.06%	6,495	0.05%	0.00052	4.477	2.55%	20,000	0.25%	0.00447
Capital Goods	175.235	4.54%	44,715,165	17.00%	0.25517	54.87	8.95%	5,668,084	43.72%	0.10330	6.113	3.49%	883,000	11.04%	0.14445
Ind. Machines								11,813	0.09%				3,000	0.04%	
Electronics								4,770,280	36.80%		1.54	0.88%	560,000	7.00%	0.36364
Transport Equip.								873,327	6.74%		1.09	0.62%	320,000	4.00%	0.29358
Services	2,997.11	77.67%	7,393,428	2.81%	0.00247	474.048	77.35%	473,631	3.65%	0.00100	110.198	62.87%	0	0.00%	0.00000
TOTAL	3,858.78		263,091,511		0.06818	612.90		12,963,548		0.02115	175.29	108.49	8,000,000		0.04570

Source: Author’s estimations.

The low value of the Mexican pollution ICs, which are even lower than the U.S. as a whole, could be explained by the following facts: (i) the SEMARNAP HW pollution results were constructed based on Mexican manifests. The manifest is a requirement of a forecasted HW generation for any new factory to be built. In other words, HW generation is reported before the factory initiate its operation, and there is an incentive to underreport[19] the future amount of HW generation; (ii) as already mentioned, the Mexican HW classifications consider fewer forms of HW than EPA-RCRA classifications; (iii) Mexico's estimations for HW generation in the services sector are zero, whereas in California the service sector generates about 3.7 % of total HW. Considering that Mexico's services share of GDP (64.3%) is slightly lower than California (77.1%), Mexico HW generation from services should be approximately 3% or equivalent to 240,000 tons/year; (iv) furthermore, Mexico does not report contaminated soils as part of HW generated, whereas in California, contaminated soils accounts for 1,392,999 tons, representing 10.8% of total HW generated. If we consider contaminated soils as HW, then Mexico's HW generated would be increased by at least 800,000 tons, based on the 8,000,000 tons officially reported. In sum, Mexico's real HW generated should be greater than that reported by SEMARNAP. Based on the facts mentioned above, the Mexico's HW pollution should be at least 15% greater than the official quantity reported.

Taking a close look at Table 6, it can be concluded that most of the HW pollution in the three regions comes from intermediate inputs sectors. The intermediate inputs sector accounts for 56% of total HW generated in the ROUS, 51% in Mexico and 36% in California. In California, most of the HW pollution comes from capital goods sector, especially from the electronics industry, accounting for 37% of the total HW generated. In California, the chemicals industry accounts for only 5.9 % of the total HW generated. But in Mexico, the chemicals industry is the most heavily HW polluting sector accounting for 29% of the total HW generated.

The data indicates that in California, the three sectors with the highest aggregated HW pollution ICs, oil, gas and mining (0.27 ton./mill US$), intermediate goods (0.26 tons/mill.US$) and capital goods (0.10 tons/mill US$). In Mexico, primary metals (0.40 tons/mill US$), chemicals (0.39 tons/mill US$) and electronics (0.36 tons/mill US$) are the specific sectors with the highest intensity coefficients. In general, Mexican pollution ICs are higher than in California for every sector except for the manufacturing sector. Table 5.6 shows that the agricultural and food sectors generate small or no amounts of HW per unit of output.

Data from Table 6 shows that HW pollution ICs vary considerably from sector to sector and from region-to-region. Hence, the extrapolation of California HW coefficients to Mexico or other regions in the U.S., can lead to serious errors. Hence, results from studies in which pollution ICs are extrapolated should be taken with caution. Note that this is the first attempt to construct HW pollution ICs for Mexico. Hence, these are preliminary estimates. The HW pollution ICs shown in Table 6, are those used to calibrate the model.

4.2.2 Pollutant Share Coefficients.

The pollutant sectoral coefficients were estimated only for California, because of the quality of the database. California pollution disaggregation and pollution share coefficients estimations were done using the B codes (Form Code) reported in the GM Form of the BHWR of California. Since the Mexican HW pollution data was highly aggregated, it was not possible to disaggregate the total sectoral pollution by type of pollutant. Hence, the California sectoral pollutant share coefficients by types of pollutant estimated, is used to estimate HW pollution generation by type of pollutant for Mexico. This assumption can lead to some errors, since the type of pollutants depend directly on the type of production in that economic sector which could differ between California and Mexico. Due to the lack of data, this is the only feasible way to calibrate the model and to determine a preliminary HW pollution structure for Mexico.

The pollutant types are defined in a consistent way to create a linkage between type of pollutant and its treatment. This linkage also makes results feasible for use in future capacity assurance planning because the 18 pollutant categories selected are linked with different types of treatments.

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[19] For further details, see Madrid (1997).

4.2.3 Treatment Demand Coefficients.

Treatment coefficients were estimated using the California RCRA, General Manifest (GM) database, complemented with the California Assurance Plans (1989, 1992), The Treatment Technologies Applications Matrix (1994) and with information supplied by HW management. The treatment share or demand coefficients used in the calibration of the environmental model were estimated using California data. These coefficients were applied to the Mexico since there is a complete lack of HW treatment information for Mexico. Note that using California treatment coefficients for Mexico could lead to some errors, because California is a region where more sophisticated standards are in place and higher technologies are used for HW treatment. Due to the lack of Mexican treatment data, this is the only feasible way to estimate an initial treatment demand under NAFTA for Mexico.

5. SENTIVITY ANALYSIS AND SCENARIOS CONSIDERED

5.1 Description of Scenarios Considered

This research is designed to estimate sectoral pollution in California and Mexico (HW generation by type of pollutant and HW treatment demand) resulting from trade and investment integration between the U.S. and Mexico.

The first scenario (scenario 1) consists of a full trade liberalization scenario without capital liberalization. Under this scenario, all the tariff and non-tariff barriers (Table 4) among California, the ROUS, and Mexico were removed, except for those barriers with the rest of the world trade. The second scenario consist of a full trade and investment liberalization. Under this scenario all the tariff and non-tariff barriers between California, the ROUS and Mexico, except for those barriers with the rest of world trade and restrictions on direct foreign investment in Mexico were removed. The liberalization of foreign investment in Mexico is assumed to result in an exogenous 15% growth in Mexican capital stock which would reflect greater investment confidence, and an improved environment for investment.

6. RESULTS

6.1 Pollution Results

6.1.1 Pollution Results Using ICs for Mexico Based on Official HW Generation

Table A-1.1 in the Appendix shows the region's aggregated results under the two different scenarios using for Mexico the ICs presented in Table 6. Trade liberalization and investment liberalization produce relatively small changes in the production, and consequently in pollution in California. In the first scenario, HW generation increased in California by 10,710 tons (or equivalent to 0.083 % increase) and by 10,609 tons (or equivalent to 0.082% increase) in the second scenario.

For the ROUS, trade liberalization increases HW generation by 227,181 tons equivalent to an increase of 0.087%. Proportionally, HW generation increases much more in ROUS than in California. This is because of the ROUS has larger HW intensity coefficients and the change in production in light manufacturing is much greater in the ROUS than in California. The pollution results for scenario 2 (trade and investment liberalization) do not change much with respect to liberalization by itself (scenario 1).

In Mexico, trade liberalization (scenario 1) generates an additional 374,673 tons of HW (see Appendix 1, Table A-1.1), which is equivalent to an increase of 4.68%. This average change in pollution is the result of the increase in pollution in food processing (9.61%), light manufacturing (7.27%), intermediate goods (5.18%), and consumer durables (4.8%) sectors. Most of the pollution in Mexico generated by NAFTA will come from intermediate goods (212,574 tons), which represent 56.7 % of the total pollution. Under scenario 2, the Mexican HW pollution is even greater than under scenario 1, representing an increase of 391,568 tons equivalent to an increase of 4.89%. This pollution increase is the result of the increase in pollution in food processing (9.89%), light manufacturing (7.57%), intermediate goods (5.16%), and consumer durables (4.45%) sectors.

Table A-1.2 in the Appendix presents the California pollution results desegregated by types of pollutants from the two different scenarios. The results from the two scenarios are compared to the base solution with the pre-NAFTA economic structure, which considers tariffs and non-tariffs barriers among trading partners. Table 2.2 in the Appendix (scenario 1) shows that most of the increase in California pollution is in the form of spent acid/caustic solution with metals (3,283 tons), other inorganic liquids (2,386 tons), and acidic aqueous waste (2,346 tons). These three forms account for about 75% of the new HW generation. In scenario 2, the pollution structure is almost identical to the one obtained in scenario 1.

Table A-1.3 in the Appendix presents results for Mexico from the two different scenarios. The results show that most of the increase in Mexican pollution is in a form of spent acid/caustic solution with metals (112,878 tons), acidic aqueous waste (58,988 tons) and other inorganic liquids (56,737). These three forms of pollution account for about 61% of the HW generated. The results from scenario 2 are even greater. Spent acid/caustic solution with metals increases by 118,375 tons, acidic aqueous waste by 61,962 tons and other inorganic liquids by 59,418 tons. Note that the amount of spent acid/caustic solution with metals increases in Mexico about 45 times more than in California. Clearly, NAFTA does not represent any threat and challenge to Californian authorities with respect to new treatment capacity, whereas it does to Mexican authorities.

Table A-1.4 in the Appendix, presents the California treatment demand results disaggregated by types of pollutants from the two different scenarios. The results from Table 2.4 (scenario 1), show that most of the increase in treatment demand in California pollution is for aqueous treatment (6,948 tons), other treatment[20] (2,439 tons), and metal recovery (492 tons). These three forms of HW treatments account for about 92% of the new HW treatment demand generated by NAFTA. In scenario 2, the demand for the different types of HW treatment is almost identical to the one obtained in scenario 1.

Table A-1.5 in the Appendix presents Mexico's treatment demand results disaggregated by types of pollutants from the two different scenarios. Results show that most of the increase in treatment demand in Mexico HW pollution is for aqueous treatment (199,812 tons), other treatment (68,554 tons), and disposal (25,101 tons). These three forms of HW treatments account for about 78% of the new HW treatment demand generated by NAFTA.

Previous results shows that HW generation under NAFTA represents a huge challenge for HW planning in Mexico. This challenge is due that Mexico's existing HW management (treatment and regulated disposal) is approximately 960,000 tons (SERMANAP, 1996, p. 69). Hence, the additional HW generated as result of NAFTA induced growth (approximately 390,000 tons) represents about 40% of the existing HW treatment capacity in Mexico. This suggest that NAFTA will represent a great challenge for Mexican authorities in combating or generating management capacity for HW treatment.

6.1.2 International Trade and Output Results

Table A-1.6 in the Appendix contains the sectoral changes of trade (imports and exports), output (real GDP) and pollution for scenario 1. In ROUS, trade liberalization generates an average export growth of only 0.3%. Exports of corn/feedgrain shows the highest growth (18.2%) followed by program crops (1.3%). This export growth is mainly the result of increased exports to Mexico. ROUS exports of corn/feedgrain to Mexico increase by 174.4 % and program crops by 56.2% (Appendix 2, table 2.7). Imports grow, on average by 0.24 %. Imports of other agriculture products show the highest growth (7.2%) followed by fruit and vegetables (1.18%). ROUS output grows by only 0.09%. The highest output growth is corn/feedgrain (6.59%) followed by food processing (0.38%). Note that under NAFTA, the ROUS growth rates in those sectors with the highest pollution ICs, such as oil and intermediate

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[20] Other HW treatments includes treatment such as neutralization, evaporation, clarification and phase separation. For further details about this research treatment categories and their linkages with EPA classifications, see footnote on Table 1.4 of appendix 1.

goods are moderate. As a result, the HW pollution growth (0.08%) in the ROUS under NAFTA is close to GDP growth (0.09%). For further details, see Appendix 2, Table 2.6.

Table 1.6 shows that in California, trade liberalization (scenario 1) generates an average growth of exports of only 0.03%. Exports of oil, gas and mining products shows the highest growth (0.75%) followed by intermediate goods (0.15%). This export growth is mainly the result of increased exports to Mexico. California's exports to Mexico of oil, gas and mining products increase by 31.35 % and intermediate goods by 10.7%. Imports grow on average by only 0.02 %. Imports of fruit and vegetables products shows the fastest growth (0.976%) followed by other agricultural products (0.96%). California's output as a whole grows only 0.02%. The highest sectoral output growth is in program crops (0.18%) followed by intermediate goods (0.15%). Note that in California, the GDP growth of the sector with the highest pollution intensity coefficient (intermediate goods) has one of the highest growth rate. The result is that the final average growth rate of HW pollution (0.08 %) is much higher than the average rate of growth of GDP (0.02%). Consequently, in California, HW pollution grows four times faster than average output.

In Mexico, trade liberalization (scenario 1) generates an average export growth of 9.03 %. Exports of other agriculture products have the highest growth rate (88.74 %) followed by food processing (20.56%). Export growth in these sectors, is mainly the result of increased exports to ROUS and California. These results show a clear trade diversion of agriculture products, because Mexican trade with the ROW decreases by 52.16 % (Appendix 2, Table 2.7). Mexico's exports of light manufacturing products increase by 11.73%. Mexico's imports grow, on average, by 11.39 %. Imports of corn/feedgrain shows the highest growth rate (171.41%) followed by programs crops (47.46%). Mexico's aggregated output grows by 4.8%. The highest sectoral output grows is in other agricultural products (13.68%) followed by food processing (9.61%) and light manufacturing (7.27%). Note that in Mexico, the GDP growth of those sectors with the highest intensity coefficients (light manufacturing and intermediate goods) have almost the same rate of growth as that of Mexican output in general. In scenario 1, the result is that final average growth rate of HW pollution (4.68 %) is almost identical to the average rate of growth of output (4.8 %). Consequently, in Mexico, the HW pollution grows at almost the same rate as the average output growth.

Previous results shows that pollution effects under an international trade scenario is basically a function of a change in sectoral productive structure, the magnitude of aggregated economic sectors, and the sectoral HW pollution ICs. Hence, consistent environmental policies should consider differentiation among economic sectors according to their polluting capacity.

6.1.3 Pollution Results-Mexico's ICs Sensitivity Analysis

Since, Mexico's official data for HW generation seems to be underreporting the total HW generated, a sensitivity analysis was conducted by increasing Mexico's HW pollution ICs by 20%. For the services sector, the California's services sector IC was extrapolated to Mexico.

Table A-1.8 in the Appendix shows the region's aggregated results under the two different scenarios. Trade liberalization and investment liberalization results for California and the ROUS are identical to those presented in previous section. In the first scenario, HW generation increased in California by 10,710 tons (or equivalent to 0.083 % increase) and by 10,609 tons (or equivalent to 0.082% increase) for the second scenario.

In Mexico, trade liberalization (scenario 1) generates an additional 2,164,763 tons of HW equivalent to an increase of 27.06%. This average change in pollution is the result of expansion in pollution in food processing (31.5%), light manufacturing (28.7%), intermediate goods (26.2%), and consumer durables (25.7%) sectors. Most of the pollution in Mexico will come from intermediate goods (1,075,089 tons) which represent 49.6 % of the total HW pollution. Under scenario 2, the Mexican HW pollution is even greater than under scenario 1, representing an increase of 2,185,289 tons, equivalent to an increase of 27.31%. This pollution increase is the result of the expansion of pollution in food processing (31.9%), light manufacturing (29.1%), intermediate goods (26.5%), and consumer durables (26.1%) sectors.

Note that if Mexico's ICs are underestimated by 20%, the additional HW generation (2,185,289 tons) as result of NAFTA induced growth, would represent more than two times of the existing treatment capacity in Mexico (estimated in 960,000 tons). This suggests in that case, NAFTA will represent a tremendous challenge for Mexican authorities in combating HW pollution, and especially generating HW treatment and management capacity in the future.

7. CONCLUSIONS

At first glance, several general conclusions can be drawn from this research. First, the study shows that pollution intensity coefficients (ICs) should not be extrapolated from region to region, since this type of assumption can lead to serious errors. Even within the U.S., it is clear that ICs can vary by a factor of three from one region to another. Thus, the results from previous studies in which ICs have been extrapolated should be taken cautiously. Secondly, Mexico's official HW generation statistics should be used with caution because they are the first official HW generation statistics, and may well understate HW pollution by a considerable margin. Thirdly, the comparison of California and the ROUS, HW pollution ICs reveals that California's more demanding HW regulation and the minimization and reduction programs implemented, have led to a reduction of the HW pollution by more than 50%.

The CGE results suggest that the HW pollution results are much more sensitive to trade liberalization than to trade/investment liberalization. In Mexico, trade liberalization by itself generates an increase of 4.68% (equivalent to approximately 374,000 tons) in HW pollution whereas trade and investment liberalization together, would increase pollution by only 4.89% in Mexico (equivalent to approximately 390,000 tons). While trade liberalization, by itself, could increase HW pollution considerably in Mexico (4.68%), it does so only 0.08 % in California or equivalent to approximately 10,700 tons (see appendix, Table A-1.1).

Results show that NAFTA should also induce some growth in California (0.02%), especially in those economic sectors with the highest pollution intensity coefficient such as intermediate inputs. As result, California's GDP should grow by only 0.02% and HW pollution by 0.08%. On the Mexican side, the growth is achieved almost uniformly across most of the economic sectors. The final result is that the Mexican GDP will grow by 4.8%, with HW pollution growing by only 4.68 % (see appendix, Table 1.6). Thus, an important lesson from this study, is that pollution effect under an international trade scenario, is basically a function of the change in the productive structure, the magnitude of aggregate economic activities, and the sectoral pollution ICs of the countries involved in trade. Hence, consistent environmental policies should consider differentiation among economic sectors according to their polluting capacity.

Demand treatment results show that most of the increased pollution in Mexico will be in the form of spent acid/caustic solution with metals, acid aqueous waste and other inorganic liquids. Thus, future investment for treatment capacity in Mexico should be directed at increasing aqueous treatment, other treatments (e.g. neutralization, evaporation, clarification and phase separation), and disposal capacity.

HW generation results shows that the additional HW pollution (10,700 tons) resulting from the growth attributed to NAFTA, represents little challenge for California authorities due to the relatively small change (0.08%) in the generation of HW in California. California, moreover, is adequately protected of induced growth from NAFTA in terms of treatment capacity. In Mexico the additional HW generation (390,000 tons) represents a huge challenge in terms of treatment capacity, because this additional HW generation represent 40% of the existing treatment capacity which is estimated in only 960,000 tons a year. Additionally, the sectors with the highest pollution ICs (electronics, chemicals) are the fastest growing economic sectors in the Mexican economy, especially in the maquilladora sector (Perry et al., 1990). Mexico's ICs sensitivity analysis results show that in the case that Mexico's ICs are understated by 20%, the additional HW generation as a result of NAFTA's induced growth, could be approximately 2,185,000 tons or equivalent to an increase in pollution of 27.3 %. This new generation represent more than 200% of Mexico's existing treatment capacity. In this case, HW pollution induced by NAFTA will represent a huge challenge for Mexican authorities.

Under the trade liberalization scenario (scenario 1), the pollution results obtained in this research are contrary to those estimated by Grossman and Krueger (G&K), 1993. G&K estimates that trade liberalization lead to a slight toxic pollution reduction in Mexico (-118 tons) whereas this study estimates that HW pollution will increase by approximately 374,000 tons. But, in the second scenario (trade and investment liberalization), the results of this research are consistent with those found by G&K. This consistency is only in the sense that pollution increases, but the quantity determined by both studies is completely different due to the different data bases[21] used. G&K found that toxic pollution will increase in Mexico by only 4,757 tons, whereas this study found that HW pollution will increase by approximately 390,000 tons equivalent to 4.89%.

The G&K contrary results with respect to the trade liberalization scenario (scenario 1), can be partially explained by the fact that G&K's study used the 1992-TRI database.[22] The total amount reported under TRI database is very small (especially in 1992, because it included only 320 chemicals substances). Moreover, TRI is not a very representative database of total toxic emissions, because it is limited to the manufacturing sector (SIC codes from 20 to 39) and only considers a fewer number of pollutants[23] than the RCRA. The database used in this research (RCRA HW Report), covers all the economic sectors (SIC codes from 01 to 89), and is representative of toxic as well as non-toxic wastes, but limited only to solid and aqueous wastes. The RCRA HW report does not include air pollution, whereas TRI does. The RCRA HW report estimates 276 million tons of HW (in 1993), of which approximately 51 million tons were toxic. On the other hand, the total pollution reported under TRI (in 1995), once 286 new categories were included, is only 1 million tons of toxic substances. In sum, the total pollution (in tons) reported under RCRA is about 276 larger than that of TRI. Another factors that could explain the differences are that G&K uses TRI data to estimate toxic pollution in Mexico whereas this research estimates the real HW pollution ICs for Mexico. Moreover, G&K's study covered only the manufacturing sector in a disaggregated way, whereas this study covered all the economic sectors, but in a more aggregated way. Note that TRI is a relatively new and small database (it does not cover all the economic sectors and all the toxic pollutants). In addition, TRI database is biased toward large users/importers and manufacturing sector. There have been a tendency of using TRI for empirical studies to generate a "general theory" about international trade and its effect on the environment. It is this researcher's opinion that the use of TRI database for generating theory about pollution and trade, especially as applied to LDCs to estimate ICs, could lead to erroneous results.

Results show that NAFTA should induce considerable economic growth in Mexico. This growth could result in an increase of Mexican GDP by approximately 4.9% or equivalent to a gain of US$ 8.7 billion during its implementation (a decade). This study shows that this additional growth resulting from NAFTA could generate at least an additional 390,000 tons of HW. Based on Mexican treatment costs[24], the cost of abatement for these 390,000 tons of HW is approximately US$63 millions. In industrial developed economies, HW abatement cost

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[21] G&K used the Toxic Releases Inventory Database (TRI) whereas in this research the RCRA database is used. The total quantity of pollution reported under the two databases (TRI and RCRA) are very different. The RCRA HW Report estimated 276,055,000 tons of HW for the US (1993) of which 50,959,102 were toxic wastes (RCRA HW Report, 1993, page 4-16). On the other hand, TRI total quantity reported in 1995 was only 2,208,749,000 pounds or equivalent to only 1,003,976 tons of toxic substances. Very few toxic wastes reported under RCRA are reported in TRI as toxic substances.

[22] TRI data based was established under the "Emergency Planning and Community Right-to-Know Act" (EPCRA) of 1986. Until 1995, TRI used to reports release of 322 chemicals toxic substances into the air, water, and as underground and solid waste. The reporting requirement is for those who produce/import/process 25,000 pounds or more of any TRI chemicals in a given year. Thus, only large generators are included. In 1994, an additional 286 substances were added to TRI.

[23] Note that by 1992, TRI classifications were only 316 chemicals and 20 chemicals categories. In 1994, EPA added 286 chemicals and chemicals categories (first report by July 1996). By Spring 1997, EPA is proposing to expand TRI database. This expansion will include metal, mining, coal mining, electrical utilities and RCRA subtitle C of hazardous waste (1995 TRI Public Data Base Release, p.5). The first report including these new categories will be by July 1988. Thus, 1992 TRI used by G&K does not give a comprehensive picture of toxic emissions in the U.S. because not all toxic chemicals are included under its classifications and non-manufacturing facilities are not required to report.

[24] The average treatment cost of 1 ton of HW in Mexico is U$ 162 (Madrid, 1997, p. 140).

represents between 15% to 25% of total pollution abatement costs.[25] Thus, if we assume that one gets the same effects than obtained in this research for air, water and solid waste pollution, then, the abatement cost of total pollution (air water, solid, HW) resulting from the growth generated by NAFTA should be around US$300 million. Hence, in general, it could be assumed that NAFTA free-trade agreement could generate several times the resources needed to implement an intensive HW pollution program in Mexico. Therefore, international trade could be the vehicle to generate the resources for implementing an efficient environmental policy that could lead to sustainable development in Mexico, but money alone will do nothing to abate HW pollution in Mexico. The only way to achieve this goal, is by having a governmental commitment to implement a tough regulatory framework and enforcement policy which would allow the development of the HW markets and the elimination of the natural free-riding and rent seeking activities of Mexico (Madrid, 1997). Otherwise, resources will be wasted in bureaucratic institutions, and in rent-seeking activities without any positive result.

It is important to mention that existing differences in HW regulations, fines and enforcement practices between the U.S. and Mexico, especially between California and Mexico, could act as an incentive for reallocation of industries. Several studies (Harrison, (1992), Low (1992) and the Government of Canada (CEC, 1995)) argue that reallocation of industries is unlikely. The factors that these studies identified can be summarized as follows: (i) pollution abatement cost are in average only one percent[26] of total value added; (ii) future enforcement of Mexican standards is likely to increase, thereby undermining any long-term savings expected from reallocation. In addition, some studies (G&K, 1992) argue that evidence from maquiladora industry activity, indicates that industrial reallocation to Mexico is driven by low labor costs, not by low pollution abatement costs. If this assumption is true, then labor cost saving reallocations will bring implicitly HW migration to Mexico, since a large proportion of maquiladoras are mainly in electronic sectors, which shows one of the highest HW pollution intensity coefficients. Moreover, it is important noting that HW polluting industries abatement costs are much higher than the average of 1.1% for the average for the whole economy. Empirical evidence shows that the abatement cost for heavily HW polluting industries are around 4% of total value added (Harrison, 1992, p.7). In addition, the main concern for a HW generator located in a developed country (e.g., in the US) where enforcement and fines are strictly enforced, is the threat or expected loss of the "implicit" fine (shut-down threat) and the "liabilities" issues. Madrid (1997) shows that these two issues are not enforced at all in Mexico; hence, they do not represent any threat (expected loss) to a HW generator in Mexico.[27]

Thus, based on the following factors[28]; (i) the low level of wages in Mexico which creates incentives for industrial reallocation; (ii) a weak environmental regulatory and enforcement framework in Mexico, together with the low levels of expected fines (explicit and implicit) and liabilities; (iii) the high level of expected liability and implicit fines in developed countries, especially in the US; and (iv) the high HW pollution abatement cost as share of value added of heavily HW polluting industries in the US compared with Mexico, it is more than likely that reallocation of heavily HW polluting industries (e.g., electronics, chemicals, and metal) will happen in the future. In addition, if the heavily HW polluting industries do not move some of their existing capacity to Mexico, it is very likely that most of the new

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[25] For further details about abatement costs for different U.S. industries, see Harrison (1992).

[26] Harrison (1992) shows that in the U.S., the total pollution abatement cost represents an average of only 1.1% of value added. The highest abatement cost is found in the copper industry (22 % of sectoral value added) followed by petroleum (9.3 %) and electrometallurgic steel (7.3 %).

[27] The average non-compliance fine in Mexico in 1996 was only U$ 382 per occurrence. As result of the low level of inspections, and low level of fines in Mexico, Madrid (1997, p.85) estimated that the HW generator expected loss in case of being held in non-complinace and fined is only U$ 85, which is equivalent of the treatment of less than 1 ton of HW in Mexico. Hence, any HW generator which generates more than 1 ton of HW have an incentive to free-ride.

[28] For further details, see Madrid (1997).

production capacity will expand in Mexico.[29] Hence, future research should be directed toward tracking the reallocation of industries, especially those with high intensity coefficients (electronics, chemicals, and metal) in order to analyze the effect of asymmetric environmental regulations, fines and enforcement under international trade framework.

Generalizations about how international trade will affect the environment (positive or negative effect) cannot be easily obtained, especially when a LDC is involved in trade. The effect of trade on the environment is a very complex phenomenon, which should not be generalized using only the results from broad quantitative economic studies as the CGE presented here. Pure broad quantitative economic studies should be complemented with other types of studies (e.g., institutional, comparative, or case studies), especially country specific studies, to obtain a better understanding of the effect of international trade on the environment. For example, this research's quantitative study (the CGE model) shows that trade can generate enough economic resources for pollution abatement; thus, one may conclude that trade is beneficial for the environment. Madrid (1997) conducted an institutional and comparative study which shows that if Mexican institutions are not improved (e.g., environmental regulation, enforcement and fine policies, the need for the development of HW markets, and rent-seeking activities should be reduced, etc) resources or gain from free trade will be wasted, and thereby free trade would be damaging for the environment in Mexico. Madrid (1997) shows that the final effect of trade on the environment will depend on many variables, such as (i) the type of pollution (air, water, HW, toxic waste, etc.) and its abatement cost; (ii) the magnitude and structure of the economies involved in trade; (iii) the changes that free trade generates on the structure of the economy; (iv) the sectoral pollution ICs; (v) the level of governmental commitment which is linked to the type of pollution, asymmetry of information, public pressure, and political gains; (vi) the quality of enforcement and level of fines for non-compliance; (iv) the quality of the environmental regulation in place; (vii) the level of the income per capita of the countries involved in trade; (viii) the country's institutional arrangements and its constraints (e.g., political, economic, human resources, etc); and finally, (ix) the efficiency and resources given to environmental multilateral institutions (e.g., CEC in NAFTA).

Finally, this study shows that an appropriately designed environmental CGE model could be used for designing capacity assurance plans under different economic scenarios. Hence, a CGE model can be a useful tool for an environmental planner.

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[29] Today, a large proportion of the new production of electronics is establishing in Mexico as maquiladoras to take advantage of the maquiladora program benefits as well as NAFTA benefits.

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APPENDIX 1:
TABLE A-1.1: Total Agreggated Sectoral Hazardous Waste Pollution Results

Results from Scenario 1 (Trade Liberalization)

Sector	REST OF THE U.S.			CALIFORNIA			MEXICO		
	Total Pollution (tons)	Change in Pollution (ton)	Change (%)	Total Pollution (tons)	Change in Pollution (tons)	Change %	Total Pollution (tons)	Change in Pollution tons)	Change %
Corn/Feedgrains	0	0	0.000%	0	0	0.000%	0	0	0.000%
Program Crops	0	0	0.000%	0	0	0.000%	0	0	0.000%
Fruit and Vegetables	0	0	0.000%	0	0	0.000%	0	0	0.000%
Other Agriculture	2,225	-13	-0.581%	113	-1	-0.877%	0	0	0.000%
Food Processing	46,178	175	0.380%	4,781	3	0.063%	526,133	46,133	9.611%
Light Manufacturing	1,114,869	1,712	0.154%	51,022	20	0.039%	1,069,444	72,444	7.266%
Oil, Gas, Mining	61,428,721	0	0.000%	2,070,772	0	0.000%	1,525,293	5,293	0.348%
Intermediate Goods	148,483,982	180,061	0.121%	4,695,710	7,038	0.150%	4,312,574	212,574	5.185%
Consumer Durables	89,041	163	0.183%	6,498	3	0.046%	20,959	959	4.795%
Capital Goods	44,754,717	39,552	0.088%	5,671,700	3,616	0.064%	920,270	37,270	4.221%
Services	7,398,959	5,531	0.075%	473,662	31	0.007%	0	0	0.000%
TOTAL	263,318,692	227,181	0.0863%	12,974,258	10,710	0.0826%	8,374,673	374,673	4.683%

Results from Scenario 2 (Trade and Investment Liberalization)

Sector	REST OF THE U.S.			CALIFORNIA			MEXICO		
	Total Pollution (tons)	Change in Pollution (ton)	Change (%)	Total Pollution (tons)	Change in Pollution (tons)	Change %	Total Pollution (tons)	Change in Pollution tons)	Change %
Corn/Feedgrains	0	0.0	0.000%	0	0	0.000%	0	0	0.000%
Program Crops	0	0.0	0.000%	0	0	0.000%	0	0	0.000%
Fruit and Vegetables	0	0.0	0.000%	0	0	0.000%	0	0	0.000%
Other Agriculture	2,225	-13	-0.581%	113	-1	-0.877%	0	0	0.000%
Food Processing	46,195	192	0.417%	4,781	3	0.063%	527,479	47,479	9.890%
Light Manufacturing	1,114,876	1,719	0.154%	51,022	20	0.039%	1,072,520	75,520	7.570%
Oil, Gas, Mining	61,428,721	0	0.000%	2,070,772	0	0.000%	1,525,028	5,028	0.330%
Intermediate Goods	148,485,268	181,347	0.122%	4,695,710	7,038	0.150%	4,323,177	223,177	5.440%
Consumer Durables	89,041	163	0.183%	6,498	3	0.046%	21,031	1,031	5,160%
Capital Goods	44,754,462	39,297	0.088%	5,671,596	3,512	0.062%	922,333	39,333	4.450%
Services	7,398,062	5,634	0.076%	473,665	34	0.007%	0	0	0.000%
TOTAL	263,319,850	228,339	0.0867%	12,974,157	10,609	0.0818%	8,391,568	391,568	4.895%

APPENDIX 1:

TABLE A-1.2 : California HW Pollution Results Disagregated by Types of Pollutant (in tons)

California HW Generation Disaggregated by Pollutant Type (Scenario 1-Trade Liberalization)

Pollutant Type	Corn/ Grains	Program Crops	Fruit and Veges.	Other Agriculture	Food Processing	Light Man.	Oil, Gas, Mining	Intermediate Goods	Consumer Durables	Capital Goods	Services	TOTAL
P1	0	0	0	0	0	0	0	53	0	1	15	69
P2	0	0	0	-1	0	0	0	199	0	89	0	288
P3	0	0	0	0	0	6	0	2,777	3	497	0	3,283
P4	0	0	0	0	0	2	0	4	0	883	1	890
P5	0	0	0	0	0	0	0	1,749	0	597	0	2,346
P6	0	0	0	0	0	2	0	1,138	0	1,243	3	2,386
P7	0	0	0	0	1	1	0	24	0	13	2	41
P8	0	0	0	0	0	1	0	34	0	30	1	66
P9	0	0	0	0	0	3	0	13	0	4	0	20
P10	0	0	0	0	0	3	0	28	0	5	1	37
P11	0	0	0	0	0	0	0	43	0	16	4	63
P12	0	0	0	0	0	0	0	31	0	9	0	40
P13	0	0	0	0	1	0	0	123	0	10	1	135
P14	0	0	0	0	0	1	0	372	0	192	2	567
P15	0	0	0	0	0	0	0	197	0	7	0	204
P16	0	0	0	0	1	0	0	245	0	19	0	265
P17	0	0	0	0	0	0	0	8	0	1	1	10
P18	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	-1	3	20	0	7,038	3	3,616	31	10,710

California HW Generation Disaggregated by Pollutant Type (Scenario 2-Trade & Investment Liberalization)

Pollutant	Corn/ Grains	Program Crops	Fruit and Veges.	Other Agriculture	Food Processing	Light Man.	Oil, Gas, Mining	Intermediate Goods	Consumer Durables	Capital Goods	Services	TOTAL
P1	0	0	0	0	0	0	0	53	0	1	16	70
P2	0	0	0	-1	0	1	0	199	0	86	0	285
P3	0	0	0	0	0	6	0	2,777	3	483	0	3,269
P4	0	0	0	0	0	2	0	4	0	857	1	864
P5	0	0	0	0	0	0	0	1,749	0	580	0	2,329
P6	0	0	0	0	0	2	0	1,138	0	1,208	3	2,351
P7	0	0	0	0	1	1	0	24	0	13	2	41
P8	0	0	0	0	0	0	0	34	0	29	2	66
P9	0	0	0	0	0	3	0	13	0	4	0	20
P10	0	0	0	0	0	3	0	28	0	5	1	37
P11	0	0	0	0	0	0	0	43	0	15	5	63
P12	0	0	0	0	0	0	0	31	0	9	0	40
P13	0	0	0	0	1	0	0	123	0	10	1	135
P14	0	0	0	0	0	1	0	372	0	187	2	562
P15	0	0	0	0	0	0	0	197	0	6	0	203
P16	0	0	0	0	1	0	0	245	0	18	0	264
P17	0	0	0	0	0	0	0	8	0	1	1	10
P18	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	-1	3	20	0	7,038	3	3,512	34	10,609

P1: Lab Packs. EPA Codes B001..B009
P2: Aqueous waste with solvents/other toxics. EPA codes B100,B102

P3: Spent acid/caustic solution with metals.EPA codes B103, B106, B107

P4: Spent acid/caustic solution without metals. EPA codes B104
P5: Acidic aqueous waste. EPA codes B105

P6: Other Inorganic Liquids.EPA codes B108..B119
P7: Halogenated/Nonhalogenated solvents. EPA codes B201..B204

P8: Oil/Waste oil. EPA codes B205, B206

P10: Other organic Liquids. EPA codes B207,B219
P11: Contaminated soils. EPA codes B301..B304

P12: Inorganic solids with metals. EPA codes B306..B309

P13: Inorganic solids/chemicals. EPA codes B310..B318
P14: Other inorganic solids. EPA codes B305,B319

P15: Organic solids. EPA codes 401..B409
P16: Inorganic sludges. EPA codes B501..B519

P17: Organic sludges. EPA codes B601..B608

P9: Paint, ink, thinner, epoxies. EPA codes B208..B212 .

P18: Organic/inorganic gases. EPA codes B701,B801

APPENDIX 1:
TABLE A-1.3: Mexico HW Pollution Results Disaggregated by Types of Pollutant (in tons)

Mexico HW Generation Disaggregated by Pollutant Type (Scenario 1-Trade Liberalization)

Pollutant	Corn/ Grains	Program Crops	Fruit and Veges.	Other Agriculture	Food Processing	Light Man.	Oil, Gas, Mining	Intermediate Goods	Consumer Durables	Capital Goods	Services	TOTAL
P1	0	0	0	0	18	41	0	1,615	0	9	0	1,683
P2	0	0	0	0	145	1,447	0	6,000	0	913	0	8,505
P3	0	0	0	0	723	22,401	0	83,858	769	5,127	0	112,878
P4	0	0	0	0	0	6,072	4	133	0	9,098	0	15,307
P5	0	0	0	0	0	17	0	52,814	0	6,156	0	58,988
P6	0	0	0	0	1,365	6,733	1,422	34,378	23	12,817	0	56,737
P7	0	0	0	0	7,179	4,197	0	727	3	136	0	12,242
P8	0	0	0	0	4,069	1,708	100	1,014	0	304	0	7,195
P9	0	0	0	0	253	11,593	1	380	0	42	0	12,269
P10	0	0	0	0	633	12,055	9	849	0	54	0	13,600
P11	0	0	0	0	36	1,194	3,251	1,312	137	162	0	6,092
P12	0	0	0	0	172	465	3	937	0	92	0	1,669
P13	0	0	0	0	12,107	579	17	3,708	16	106	0	16,533
P14	0	0	0	0	9	1,732	108	11,231	0	1,980	0	15,060
P15	0	0	0	0	380	593	94	5,965	3	67	0	7,102
P16	0	0	0	0	18,673	543	213	7,401	0	194	0	27,024
P17	0	0	0	0	326	1,073	71	251	8	12	0	1,741
P18	0	0	0	0	45	1	0	1	0	1	0	48
Total	0	0	0	0	46,133	72,444	5,293	212,574	959	37,270	0	374,673

Mexico HW Generation Disaggregated by Pollutant Type (Scenario 2-Trade and Investment Liberalization)

Pollutant	Corn/ Grains	Program Crops	Fruit and Veges.	Other Agriculture	Food Processing	Light Man.	Oil, Gas, Mining	Intermediate Goods	Consumer Durables	Capital Goods	Services	TOTAL
P1	0	0	0	0	19	43	0	1,696	0	10	0	1,768
P2	0	0	0	0	149	1,509	0	6,299	0	964	0	8,921
P3	0	0	0	0	744	23,353	0	88,039	828	5,411	0	118,375
P4	0	0	0	0	0	6,330	4	140	0	9,601	0	16,075
P5	0	0	0	0	0	17	0	55,449	0	6,497	0	61,963
P6	0	0	0	0	1,405	7,019	1,351	36,093	25	13,525	0	59,418
P7	0	0	0	0	7,389	4,375	0	764	3	144	0	12,675
P8	0	0	0	0	4,188	1,780	95	1,065	0	321	0	7,449
P9	0	0	0	0	261	12,0,85	1	399	0	44	0	12,790
P10	0	0	0	0	651	12,567	8	891	0	57	0	14,174
P11	0	0	0	0	37	1,244	3,088	1,378	147	171	0	6,065
P12	0	0	0	0	177	484	3	983	0	97	0	1,744
P13	0	0	0	0	12,461	604	16	3,893	17	112	0	17,103
P14	0	0	0	0	9	1,805	103	11,791	0	2,090	0	15,798
P15	0	0	0	0	391	619	90	6,262	3	71	0	7,436
P16	0	0	0	0	19,216	566	202	7,771	0	204	0	27,959
P17	0	0	0	0	335	1,119	67	263	8	13	0	1805
P18	0	0	0	0	47	1	0	1	0	1	0	50
Total	0	0	0	0	47,479	75,520	5,028	223,177	1,031	39,333	0	391568

P1: Lab Packs
P2: Aqueous waste with solvents/other toxics.
P3: Spent acid/caustic solution with metals.
P4: Spent acid/caustic solution without metals.
P5: Acidic aqueous waste.
P6: Other Inorganic Liquids.
P7: Halogenated/Nonhalogenated solvents.
P8: Oil/Waste oil.
P9: Paint, ink, thinner, epoxies.
P10: Other organic Liquids
P11: Contaminated soils
P12: Inorganic solids with metals
P13: Inorganic solids/chemicals
P14: Other inorganic solids
P15: Organic solids
P16: Inorganic sludges
P17: Organic sludges
P18: Organic/inorganic gases

APPENDIX 1:

TABLE A-1.4 : California Treatment Demand Results (in tons)

Results from Scenario 1 (Trade Liberalization)

Pollutant Type	Metal Recovery	Solvent Recovery	Other Recovery	Incineration	Energy Recovery	Aqueous Treatment	Sludge Treatment	Stabilization	Other Treatment	Disposal	TOTAL
P1	0	0	0	8	0	0	0	0	0	61	69
P2	0	0	0	0	0	196	0	0	92	0	288
P3	492	0	0	0	0	2,791	0	0	0	0	3,283
P4	0	0	98	0	0	178	0	0	614	0	890
P5	0	0	0	0	0	1,642	0	0	704	0	2,346
P6	0	41	0	0	0	1,558	0	0	787	0	2,386
P7	0	24	0	7	10	0	0	0	0	0	41
P8	0	0	17	0	0	0	0	0	0	50	67
P9	0	5	0	6	2	0	0	0	4	3	20
P10	0	0	0	7	0	0	0	0	0	30	37
P11	0	0	0	0	0	0	0	33	6	23	62
P12	0	0	0	0	0	0	0	0	40	0	40
P13	0	0	0	0	0	0	0	41	80	14	135
P14	0	0	0	0	0	567	0	0	0	0	567
P15	0	0	92	0	0	0	0	0	112	0	204
P16	0	0	0	11	0	16	214	11	0	13	265
P17	0	0	0	0	0	0	8	2	0	0	10
P18	0	0	0	0	0	0	0	0	0	0	0
TOTAL	492	70	207	39	12	6,948	222	87	2,439	194	10,710

Results from Scenario 2 (Trade and Investment Liberalization)

Pollutant Type	Metal Recovery	Solvent Recovery	Other Recovery	Incineration	Energy Recovery	Aqueous Treatment	Sludge Treatment	Stabilization	Other Treatment	Disposal	TOTAL
P1	0	0	0	8	0	0	0	0	0	62	70
P2	0	0	0	0	0	194	0	0	91	0	285
P3	490	0	0	0	0	2,779	0	0	0	0	3,269
P4	0	0	95	0	0	173	0	0	596	0	864
P5	0	0	0	0	0	1,630	0	0	699	0	2,329
P6	0	40	0	0	0	1,535	0	0	776	0	2,351
P7	0	24	0	7	10	0	0	0	0	0	41
P8	0	0	17	0	0	0	0	0	0	49	66
P9	0	5	0	6	2	0	0	0	4	3	20
P10	0	0	0	7	0	0	0	0	0	30	37
P11	0	0	0	0	0	0	0	34	6	23	63
P12	0	0	0	0	0	0	0	0	40	0	40
P13	0	0	0	0	0	0	0	41	80	14	135
P14	0	0	0	0	0	562	0	0	0	0	562
P15	0	0	91	0	0	0	0	0	112	0	203
P16	0	0	0	11	0	16	213	11	0	13	264
P17	0	0	0	0	0	0	8	2	0	0	10
P18	0	0	0	0	0	0	0	0	0	0	0
TOTAL	490	69	203	39	12	6,889	221	88	2,404	194	10,609

P1: Lab Packs
P2: Aqueous waste with solvents/other toxics.
P3: Spent acid/caustic solution with metals.
P4: Spent acid/caustic solution without metals.
P5: Acidic aqueous waste.
P6: Other Inorganic Liquids.
P7: Halogenated/Nonhalogenated solvents.
P8: Oil/Waste oil.
P9: Paint, ink, thinner, epoxies.
P10: Other organic Liquids
P11: Contaminated soils
P12: Inorganic solids with metals
P13: Inorganic solids/chemicals
P14: Other inorganic solids
P15: Organic solids
P16: Inorganic sludges
P17: Organic sludges
P18: Organic/inorganic gases

APPENDIX 1:

TABLE A-1.5 : Mexico Treatment Demand Results (in tons)

Results from Scenario 1 (Trade Liberalization)

Pollutant Type	Metal Recovery	Solvent Recovery	Other Recovery	Incineration	Energy Recovery	Aqueous Treatment	Sludge Treatment	Stabilization	Other Treatment	Disposal	TOTAL
P1	0	0	0	202	0	0	0	0	0	1,481	1,683
P2	0	0	0	0	0	5,783	0	0	2,722	0	8,505
P3	16,932	0	0	0	0	95,946	0	0	0	0	112,878
P4	0	0	1,684	0	0	3,061	0	0	10,562	0	15,307
P5	0	0	0	0	0	41,292	0	0	17,696	0	58,988
P6	0	965	0	0	0	37,049	0	0	18,723	0	56,737
P7	0	7,222	0	1,959	3,061	0	0	0	0	0	12,242
P8	0	0	1,799	0	0	0	0	0	0	5,396	7,195
P9	0	2,822	0	3,435	1,227	0	0	0	2,699	2,086	12,269
P10	0	0	0	2,720	0	0	0	0	0	10,880	13,600
P11	0	0	0	0	0	0	0	3,229	609	2,254	6,092
P12	0	0	0	0	0	0	0	0	1,669	0	1,669
P13	0	0	0	0	0	0	0	4,960	9,920	1,653	16,533
P14	0	0	0	0	0	15,060	0	0	0	0	15,060
P15	0	0	3,196	0	0	0	0	0	3,906	0	7,102
P16	0	0	0	1,081	0	1,621	21,890	1,081	0	1,351	27,024
P17	0	0	0	0	70	0	1,392	279	0	0	1,741
P18	0	0	0	0	0	0	0	0	48	0	48
TOTAL	16,932	11,009	6,679	9,397	4,358	199,812	23,282	9,549	68,554	25,101	374,673

Results from Scenario 2 (Trade and Investment Liberalization)

Pollutant Type	Metal Recovery	Solvent Recovery	Other Recovery	Incineration	Energy Recovery	Aqueous Treatment	Sludge Treatment	Stabilization	Other Treatment	Disposal	TOTAL
P1	0	0	0	212	0	0	0	0	0	1,556	1,768
P2	0	0	0	0	0	6,066	0	0	2,855	0	8,921
P3	17,756	0	0	0	0	100,619	0	0	0	0	118,375
P4	0	0	1,768	0	0	3,215	0	0	11,092	0	16,075
P5	0	0	0	0	0	43,374	0	0	18,589	0	61,963
P6	0	1,010	0	0	0	38,800	0	0	19,608	0	59,414
P7	0	7,478	0	2,020	3,169	0	0	0	0	0	12,675
P8	0	0	1,862	0	0	0	0	0	0	5,587	7,449
P9	0	2,942	0	3,581	1,279	0	0	0	2,814	2,174	12,790
P10	0	0	0	2,835	0	0	0	0	0	11,339	14,174
P11	0	0	0	0	0	0	0	3,214	607	2,244	6,065
P12	0	0	0	0	0	0	0	0	1,744	0	1,744
P13	0	0	0	0	0	0	0	5,131	10,262	1,710	17,103
P14	0	0	0	0	0	15,798	0	0	0	0	15,798
P15	0	0	3,346	0	0	0	0	0	4,090	0	7,436
P16	0	0	0	1,118	0	1,678	22,647	1,118	0	1,398	27,959
P17	0	0	0	0	72	0	1,444	289	0	0	1,805
P18	0	0	0	0	0	0	0	0	50	0	50
TOTAL	17,756	11,430	6,976	9,774	4,520	209,550	24,091	9,752	71,711	26,008	391,568

P1: Lab Packs
P2: Aqueous waste with solvents/other toxics.
P3: Spent acid/caustic solution with metals.
P4: Spent acid/caustic solution without metals.
P5: Acidic aqueous waste.
P6: Other Inorganic Liquids.
P7: Halogenated/Nonhalogenated solvents.
P8: Oil/Waste oil.
P9: Paint, ink, thinner, epoxies.
P10: Other organic Liquids
P11: Contaminated soils
P12: Inorganic solids with metals
P13: Inorganic solids/chemicals
P14: Other inorganic solids
P15: Organic solids
P16: Inorganic sludges
P17: Organic sludges
P18: Organic/inorganic gases

APPENDIX 1:
TABLE A-1.6: Aggregated Trade and Output Results (Scenario 1-Trade Liberalization)

Sector	ROUS (% change).				CALIFORNIA (% change)				MEXICO (% change)			
	Exports (%)	Imports (%)	GDP (%)	Pollution (%)	Exports (%)	Imports (%)	GDP (%)	Pollution (%)	Exports (%)	Imports (%)	GDP (%)	Pollution (%)
Corn/Feedgrains	18.17	0.00	6.59	0.000	0.00	0.00	0.00	0.000	0.00	171.41	-9.53	0.000

Program Crops	1.30	-0.43	0.31	0.000	0.00	-0.16	0.18	0.000	0.00	47.46	0.07	0.000
Fruit & Vegetables	-0.10	1.18	-0.12	0.000	0.00	0.97	0.06	0.000	9.49	39.13	7.55	0.000
Other Agriculture	-0.63	7.16	-0.57	-0.581	-0.93	0.96	-0.93	-0.877	88.74	17.39	13.68	0.000
Food Processing	0.59	0.09	0.38	0.380	-0.20	-0.05	0.06	0.063	20.56	14.62	9.61	9.611
Light Manufacturing	0.22	0.14	0.15	0.154	0.05	-0.01	0.04	0.039	11.73	12.41	7.27	7.266
Oil, Gas, Mining	0.55	0.41	0.00	0.000	0.78	0.23	0.01	0.000	4.27	25.52	0.35	0.348
Intermediate Goods	0.25	0.13	0.12	0.121	0.15	0.01	0.15	0.150	4.70	8.29	5.18	5.185
Consumer Durables	0.54	0.08	0.18	0.183	0.04	0.00	0.04	0.046	6.77	10.27	4.80	4.795
Capital Goods	0.18	0.06	0.09	0.088	0.07	-0.01	0.06	0.064	6.37	6.69	4.22	4.211
Services	0.10	0.02	0.08	0.075	0.02	-0.08	0.01	0.007	3.40	4.25	4.50	0.000
TOTAL	0.30	0.24	0.09	0.086	0.03	0.02	0.02	0.083	9.03	11.39	4.80	4.683

TABLE A-1.7 Disagregated Trade Results (in percentage)

Exports Change in Percentage (Scenario 1)

Sector	Exports from ROUS to (% change).			Exports from CALIFORNIA to			Exports from MEXICO to		
	CA	MX	ROW	ROUS	MX	ROW	ROUS	CA	ROW
Corn/Feedgrains	0.00	171.41	-15.27	0.00	0.00	0.00	0.00	0.00	0.00
Program Crops	-0.09	56.25	-1.37	-0.32	48.47	0.55	0.00	-0.05	-0.09
Fruit and Vegetables	-0.60	36.78	0.52	-0.32	36.82	0.74	19.91	19.75	7.35
Other Agriculture	-1.87	19.63	0.97	-1.10	15.98	1.39	130.35	140.65	-52.16
Food Processing	-0.13	17.74	1.27	-0.48	16.17	1.57	44.1	44.03	-0.79
Light Manufacturing	-0.06	14.67	0.30	-0.21	14.66	0.19	14.75	14.68	2.36
Oil, Gas, Mining	-0.22	31.82	-1.36	-1.02	31.35	-2.23	4.24	4.34	0.00
Intermediate Goods	-0.02	10.70	-0.06	0.00	10.70	0.09	3.32	3.28	9.91
Consumer Durables	-0.21	20.44	-0.45	-0.11	20.61	0.09	6.85	6.83	6.67
Capital Goods	-0.07	9.26	-0.04	-0.06	9.25	0.08	8.12	8.13	2.89
Services	-0.08	4.24	-0.06	0.02	4.33	-0.02	0.06	-0.02	5.53
TOTAL	-0.12	14.85	-0.16	-0.10	16.26	0.13	12.38	12.59	3.69

Imports Change in Percentage (Scenario 1)

Sector	Imports from ROUS to (% change).			Imports from CALIFORNIA to			Imports from MEXICO		
	CA	MX	ROW	ROUS	MX	ROW	ROUS	CA	ROW
Corn/Feedgrains	0.00	0.00	0.00	0.00	0.00	0.00	171.41	0.00	0.00
Program Crops	-0.32	0.00	-0.51	-0.09	-0.05	0.52	56.25	48.47	0.38
Fruit and Vegetables	-0.32	19.91	-0.41	-0.60	19.75	-0.53	36.78	36.82	8.20
Other Agriculture	-1.10	130.35	-0.91	-1.87	140.65	-1.81	19.63	15.98	5.26
Food Processing	-0.48	44.10	-0.99	-0.13	44.03	-0.09	17.74	16.17	5.38
Light Manufacturing	-0.21	14.75	-0.04	-0.06	14.68	0.42	14.67	14.66	4.07
Oil, Gas, Mining	-1.02	4.24	0.31	-0.22	4.34	0.00	31.82	31.35	-3.92
Intermediate Goods	0.00	3.32	0.05	-0.02	3.28	-0.07	10.70	10.70	3.52
Consumer Durables	-0.11	6.85	-0.05	-0.21	6.83	-0.03	20.44	20.61	-4.70
Capital Goods	-0.06	8.12	-0.04	-0.07	8.13	-0.03	9.26	9.25	1.89
Services	0.02	0.06	0.05	-0.08	-0.02	-0.03	4.24	4.33	4.25
TOTAL	-0.10	12.38	-0.02	-0.12	12.59	-0.03	14.85	16.26	0.94

APPENDIX 1

TABLA-2.8: HW Intensity Coefficients Sensitivity Analysis- Total Agreggated Sectoral Hazardous Waste Pollution Results (Case with Increased (+20%) HW ICs for Mexico)

Results from Scenario 1 (Trade Liberalization)

	REST OF THE U.S.			CALIFORNIA			MEXICO		
SECTOR	Total HW Pollution(tons)	Change in Pollution	% Change	Total HW Pollution(tons)	Change in Pollution	% Change	Total HW Pollution(tons)	Change in Pollution	% Change

Corn/Feedgrains	0	0	0.000%	0	0	0.000%	0	0	0.00%
Program Crops	0	0	0.000%	0	0	0.000%	0	0	0.00%
Fruit and Vegetables	0	0	0.000%	0	0	0.000%	0	0	0.00%
Other Agriculture	2,225	-13	-0.581%	113	-1	-0.877%	0	0	0.00%
Food Processing	46,178	175	0.380%	4,781	3	0.063%	631,360	151,360	31.53%
Light Manufacturing	1,114,869	1,712	0.154%	51,022	20	0.039%	1,283,333	286,333	28.71%
Oil, Gas, Mining	61,428,721	0	0.000%	2,070,772	0	0.000%	1,830,352	310,352	20.41%
Intermediate Goods	148,483,982	180,061	0.121%	4,695,710	7,038	0.150%	5,187,089	1,075,089	26.22%
Consumer Durables	89,041	163	0.183%	6,498	3	0.046%	25,151	5,151	25.75%
Capital Goods	44,754,717	39,552	0.088%	5,671,700	3,616	0.064%	1,104,324	221,324	25.06%
Services	7,398,959	5,531	0.075%	473,662	31	0.007%	115,154	115,154	
TOTAL	263,318,692	227,181	0.0863%	12,974,258	10,710	0.0826%	10,164,763	2,164,763	27.06%

Results from Scenario 2 (Trade and Investment Liberalization)

Sector	REST OF THE U.S.			CALIFORNIA			MEXICO		
	Total HW Pollution(tons)	Change in Pollution	% Change	Total HW Pollution(tons)	Change in Pollution	% Change	Total HW Pollution(tons)	Change in Pollution	% Change
Corn/Feedgrains	0	0.0	0.000%	0	0	0.000%	0	0	0.00%
Program Crops	0	0.0	0.000%	0	0	0.000%	0	0	0.00%
Fruit and Vegetables	0	0.0	0.000%	0	0	0.000%	0	0	0.00%
Other Agriculture	2,225	-13	-0.581%	113	-1	-0.877%	0	0	0.00%
Food Processing	46,195	192	0.417%	4,781	3	0.063%	632,975	152,975	31.87%
Light Manufacturing	1,114,876	1,719	0.154%	51,022	20	0.039%	1,287,024	290,024	29.09%
Oil, Gas, Mining	61,428,721	0	0.000%	2,070,772	0	0.000%	1,830,034	310,034	20.40%
Intermediate Goods	148,485,268	181,347	0.122%	4,695,710	7,038	0.150%	5,187,813	1,087,813	26.53%
Consumer Durables	89,041	163	0.183%	6,498	3	0.046%	25,237	5,237	26.19%
Capital Goods	44,754,462	39,297	0.088%	5,671,596	3,512	0.062%	1,106,800	223,800	25.35%
Services	7,398,062	5,634	0.076%	473,665	34	0.007%	115,406	115,406	
TOTAL	263,319,850	228,339	0.0867%	12,974,157	10,609	0.0818%	10,185,289	2,185,289	27.31%

APPENDIX 2: ENVIRONMENTAL CGE MODEL

2.1 REGIONAL, SECTORAL AND FACTOR CLASSIFICATIONS OF THE MODEL

A. Countries and Regions

c1,c2	Universe	ROUS	Rest of the US
		CA	California
		MX	Mexico
		ROW	Rest of the World
k(c1)	Countries	ROUS	Rest of the US

		CA	California
		MX	Mexico

B. Equations Indices

i	Economic sectors (note that j is an alias for i)
ie	Economic sectors that produce exports goods
im	Economic sectors that use imports goods
f	Factors of production or inputs consisting of capital, labor, and land
hh	Household
ins	Institutions
ie1	Aggregate CET exports
p1	Type of pollutants
t1	Type of treatments

C. Factors and Groupings

f	Factor of production	CAPITAL	Capital stock
		LAND	Agricultural land
		RULAB	Rural labor
		URBUNLAB	Urban unskilled labor
		UNIONLAB	Urban skilled labor
		YUPS	Professionals
i	Economic sectors	CORN	Corn and Feedgrains
		AGPROG	Other Program Crops
		FRTVEG	Fruits and Vegetables
		OTHAG	Other Agriculture
		FOOD	Food Processing
		LMFG	Light Manufacturing
		OIL	Oil, gas and mining
		INT	Intermediates Inputs
		CDUR	Consumer Durables
		KGOOD	Capial Goods
		SVC	Services

D. Households and Institutions

hh	Households	hhall	Household category
ins	Institutions	lab	Labor
		ent	Enterprises
		prop	Property income

2.2 VARIABLES OF THE ENVIRONMENTAL CGE MODEL

Price Block

EXR_k	Exchange rate
$PQ_{i,k}$	Consumption price of composite goods
$PD_{i,k}$	Domestic Prices
$PDA_{i,k}$	Processors actual domestic sales price including subsidy
$PE_{i,k,c1}$	Domestic price of exports
$PEK_{i,k}$	Average domestic price of exports
$PM_{i,k,c1}$	Domestic price of imports
$PQ_{i,k}$	Price of composite goods
$PVA_{i,k}$	Value added price including subsidies
$PVAB_{i,k}$	Value added price net of subsidies
$PWE_{i,c1,c2}$	World price of exports (exogenous)
$PWM_{i,c1,c2}$	World price of imports (exogenous)
$PX_{i,k}$	Average output price

Income Block

$ENTSAV_k$	Enterprise savings
$ENTAX_k$	Enterprise taxes
$EXPTAX_k$	Export tax revenue
$FSAVE_k$	Foreign savings
$FTAX_k$	Factor taxes
$GOVSAV_k$	Government saving
$GOVREV_k$	Government revenue
$HTAX_k$	Household taxes
$INDTAX_k$	Indirect tax revenue
$PREM_{i,k}$	Premium income form import rationing
$SSTAX_k$	Social security tax revenue
$TARIFF_{k,c1}$	Tariff revenue
$VATAX_k$	Value added taxes revenue
$YH_{hh,k}$	Household income
$YINST_{ins,k}$	Institutional income
$ZTOT_k$	Aggregate nominal investment

Production Block

$D_{i,k}$	Domestic sales of domestic output
$E_{i,c1,c2}$	Bilateral exports
$EK_{i,k}$	Aggregate sectoral exports
$INT_{i,k}$	Intermediate demand
$M_{i,c1,c2}$	Bilateral imports
$Q_{i,k}$	Composite goods supply
$SMQ_{i,k,c1}$	Import value share in total sectoral demand
$X_{i,k}$	Domestic output

Quantity Block

$AVWF_{f,k}$	Average wage with current weights
$FACTORS_{i,f,k}$	Factor demand by sector
$FS_{f,k}$	Factor supply
$WF_{f,k}$	Average factor price
$WFDIST_{i,f,k}$	Factor differential

$YFCTR_{f,k}$	Factor income

Expenditure Block

$CDD_{i,k}$	Private consumption demand
$CONTAX_{k}$	Consumption taxes
$ENTT_{k}$	Government transfers to enterprises
ESR_{k}	Enterprise savings rate
$FBAL_{k}$	Overall current account balance (exog.)
$FBOR_{k}$	Foreign borrowing by governments (exog.)
$FKAP_{k}$	Foreign capital flow to enterprises (exog.)
$FSAV_{k,c1}$	Bilateral net foreign savings
$GD_{i,k}$	Government demand by sector
$GDPVA_{k}$	Nominal expenditure by GDP
$GDTOT_{k}$	Government Real Consumption (exog.)
HHT_{k}	Government transfers to households
$ID_{i,k}$	Investment demand by sector
$SAD_{ie1,k}$	Aggre. exports productivity parameter
$ZFIX_{k}$	Fixed aggregate real investment (exog.)

Externality Effects

$SAD2_{i,k}$	Intermediate input productivity parameter
$SAC_{f,k}$	Capital goods productivity parameter
$EKPTL_{k}$	Aggregate exports of capital goods
$MKPTL_{k}$	Capital Goods imports

2.3 PARAMETERS OF THE ENVIRONMENTAL CGE MODEL

Basic Parameters

$cles_{i,hh,k}$	Household consumption shares(fixed proportions)
$EO_{i,c1,c2}$	Exports (base data)
$EKO_{i,k}$	Country total sectoral exports, all destinations (base data)
$EKPTLO_{k}$	Aggregate exports, all destinations (base data)
$entr_{k}$	Enterprise income tax rate
$etae2_{i,k}$	Externality elasticity for aggregate exports (exog.)
$etak2_{k}$	Externality elasticity for capital goods imports(exog.)
$etam2_{k}$	Externality elasticity intermediate inputs(exog.)
$ft_{i,k}$	Factor tax rate
$FSO_{f,k}$	Aggregate factor supply (base year)
$gles_{i,k}$	Government expenditure shares
$hhtr_{hh,k}$	Household income tax rate
$IO_{i,j,k}$	Input-output coefficients
mps_{hhk}	Savings propensity by households
$MKPTL_{k}$	Imports of capital goods (base year)
$PVABO_{i,k}$	Base year value added price
$PWEO_{i,c1,c2}$	World price of exports (base year)
$PWEFXO_{i}$	Benchmark world export price
$PWMO_{i,c1,c2}$	World market price of imports (base year)
$PWTC_{i,k}$	Consumer price index weights (PQ)

$RHSH_{hh,k}$	Household shares of remittance income
$\sin tyh_{hh,insk}$	Household distribution of value added income
$sprem_{i,k}$	Share of premium revenue to the government
$sstr_{f,k}$	Social Security Factor payment tax rates
$te_{i,k}$	Tax rates on exports
$thsh_{hh,k}$	Household transfer income shares
$tm_{i,k,c1}$	Tariff rates on imports
$tm2_{i,k,c1}$	Import non-tariff barrier equivalent to tariff rate
$itax_{i,k}$	Indirect tax rates
$vatr_{i,k}$	Value added tax rate
$zshr_{i,k}$	Investment demand shares

Parameters for Production Equations

$AD2_{i,k}$	CES production function shift parameter
$\alpha 2_{i,f,k}$	CES factor share parameter
$\rho_{i,k}$	CES production function exponent

Parameter for Pollution Equations.

$\theta_{i,k}$	Sectoral pollution intensity coefficient
$\lambda_{i,k,p1}$	Sectoral pollutant share coefficient
$\omega_{i,k,1}$	Treatment share or demand coefficient

Parameter for AIDS Import Demand Functions

$SMQ0_{i,k,c1}$	Base year import value share
$\alpha_{i,k,c1}$	Share parameter in AIDS function
$AQ_{i,k}$	Constant in translog price index
$\beta_{i,k,c1}$	Coefficient in AIDS function
$\gamma_{i,k,c1,c2}$	Price parameter in AIDS function

Parameters for Export Equations

$AT_{i,k}$	CET function shift parameter
$etae_{i,k}$	Export demand elasticities for ROW (exog.)
$\gamma_{i,k}$	CET function share parameter
$\rho_{ie1,k}$	CET function exponent

2.4 MODEL EQUATIONS

Quantity Equations

Domestic Output-Supply (CES production Function of primary factors)

$$(1)\quad X_{i,k} = SAD_{i,k} \quad SAD2_{i,k} \quad AD2_{i,k} \quad \sum_{f} \alpha 2_{i,f,k} \quad (FACTORS_{i,f,k}^{-\rho_{i,k}})^{-1/\rho_{i,k}}$$

Maximization Profit Condition (Marginal Revenues =Marginal Cost)

(2)

$$(1 - ft_k) \quad WF_{f,k} \quad WFDIST_{i,f,k} = (1 - Vatr_{i,k}) * PVA_{i,k} \quad SAD_{i,k} * SAD2_{i,k} * AD2_{i,k} \quad \sum_{f} [\alpha 2_{i,f,k} \quad FACTORS_{i,f,k}^{-\rho_{i,k}}]^{(-1/\rho_{i,k} - 1)}$$

Intermediate Inputs Demand

$$(3)\quad INT_{i,k} = \sum_{j} IO_{i,j,k} \quad X_{j,k}$$

Price Equations

Domestic Price of Imports Goods

$$(4)\quad PM_{im,k,c1} = PWM_{im,k} \quad EXR_k \quad [(1 + tm_{im,k,c1}) + tm2_{im,k,c1}]$$

Domestic Price of Exports Goods

$$(5)\quad PE_{ie,k,c1} = PWE_{ie,k,c1} \quad EXR_k \quad (1 - te_{ie,k})$$

Average Domestic Price of Exports

$$(6)\quad PEK_{i,k} = \frac{\sum_{c1} PE_{i,k,c1} \quad E_{i,k,c1}}{EK_{i,k}}$$

Domestic Price Net of Indirect Tax

$$(7)\quad PDA_{i,k} = (1 - itax_{i,k}) \quad PD_{i,k}$$

Price of Composite Goods Consumed

$$(8)\quad PQ_{i,k} = \frac{PD_{i,k} \quad D_{i,k} + \sum_{c1} PM_{i,k,c1} \quad M_{i,k,c1}}{Q_{i,k}}$$

Average Output Price

$$(9)\quad PX_{i,k} = \frac{PDA_{i,k} \quad D_{i,k} + \sum_{c1} PE_{i,k,c1} \quad E_{i,k,c1}}{X_{i,k}}$$

Sectoral Value Added Price (Net price)

$$(10)\quad PVA_{i,k} = PX_{i,k} - \sum_{j} IO_{j,i,k} \quad PQ_{j,k}$$

Sectoral Value Added Price Net of Subsidies

$$(11)\quad PVAB_{i,k} = \frac{(1 - itax_{i,k}) \quad PD_{i,k} \quad D_{i,k}}{X_{i,k}} + \sum_{c1} \frac{PE_{i,k,c1} \quad E_{i,k,c1}}{X_{i,k}}$$

Trade Price Consistency

$$(12)\quad PWE_{i,c1,c2} = PWM_{i,c2,c1}$$

Consumer Price Index (Cobb Douglas Function)

$$(13)\quad PINDEX_{k} = \prod_{i} PQ_{i,k}^{\;pwtc_{i,k}}$$

Income Equations

Factor Income

$$(14)\quad YFCTR_{f,k} = \sum_{i} (1 - ft_{k}) * WF_{f,k} * WFDIST_{i,f,k} * FACTORS_{i,f,k}$$

Tariff Revenue

$$(15)\quad TARIFF_{k,c1} = \sum_{i} tm_{i,k,c1} * M_{i,k,c1} * PWM_{i,k,c1} * EXR_{k}$$

Premium Income from Imports

$$(16)\quad PREM_{i,k} = \sum_{c1} tm2_{i,k,c1} * M_{i,k,c1} * PWM_{i,k,c1} * EXR_{k}$$

Indirect Tax Revenue

$$(17)\quad INDTAX_{k} = \sum_{i} itax_{i,k} * PD_{i,k} * D_{i,k}$$

Export Tax Revenue

$$(18)\quad EXPTAX_{k} = \sum_{i,c1} te_{i,k} * PWE_{i,k,c1} * E_{i,k,c1} * EXR_{k}$$

Labor Institution Income

$$(19)\quad YINST_{lab,k} = \sum_{lab} YFCTR_{lab,k}$$

Enterprise Institution Income

$$(20)\quad YINST_{ent,k} = YFCTR_{capital,k} + EXR_{k} * FKAP_{k} - ENTSAV_{k} - ENTAX_{k} + ENTT_{k} + \sum_{i} (1 - sprem_{i,k}) * PRE$$

Property Institution Income

$$(21)\quad YINST_{prop,k} = YFCTR_{land,k}$$

Household Income

$$(22)\quad YH_{hh,k} = \sum_{ins} \sin tyh_{hh,ins,k} * YINST_{ins,k} + HHT_{k} * thsh_{hh,k}$$

Enterprise Taxes

$$(23)\quad ENTAX_{k} = ENTR_{k} * (YFCTR_{capital,k} + ENTT_{k})$$

Factor Taxes

$$(24)\quad FTAX_{k} = \sum_{f,i} ft_{k} * WF_{f,k} * WFDIST_{i,f,k} * FACTORS_{i,f,k}$$

Household Taxes

(25) $HTAX_k = \sum_{hh} hhtr_{hh,k} * YH_{hh,k}$

Value Added Taxes

(26) $VATAX_k = \sum_{i} vatr_{i,k} * PVA_{i,k} * X_{i,k}$

Social Security Taxes

(27) $SSTAX_k = \sum_{f} sstr_{f,k} * YFCTR_{f,k}$

Government Revenue

(28)
$$GOVREV_k = \sum_{c1} TARIFF_{k,c1} + INDTAX_k + EXPTAX_k + FTAX_k + HTAX_k + SSTAX_k$$
$$+ \sum_{i} sprem * PREM_{i,k} + ENTAX_k + VATAX_k + FBOR_k * EXR_k$$

Government Saving

(29) $GOVSAV_k = GOVREV_k - HHT_k - ENTT_k - \sum_{i} GD_{i,k} * PQ_{i,k}$

Aggregated Household Savings

(30) $HSAV_k = \sum_{hh} mps_{hh,k} * (1 - hhtr_{hh,k}) * YH_{hh,k}$

Enterprise Saving

(31) $ENTSAV_k = entr_k * YFCTR_{capital,k}$

Total Savings = Aggregate Nominal Investment

(32) $ZTOT_k = GOVSAV_k + HSAV_k + ENTSAV_k + EXR_k * FSAVE_k$

Foreign Savings

(33) $FSAVE_k = FBAL_k - FKAP_k - FBOR_k$

Expenditure Equations

Private Consumption Demand (or private expenditure).

(34) $$CDD_{i,k} = \frac{\sum_{hh} cles_{i,hh,k} * YH_{hh,k} * (1 - hhtr_{hh,k}) * (1 - mps_{hh,k})}{PQ_{i,k}}$$

Government Demand or Expenditure by Sectors

(35) $GD_{i,k} = gles_{i,k} * GDTOT_k$

Fixed Aggregated Real Investment by sectors

(36) $ID_{i,k} = zshr_{i,k} * ZFIX_k$

Aggregated Total Investment

(37) $ZTOT_k = \sum_{i} PQ_{i,k} * ID_{i,k}$

Gross Domestic Product Equations

Nominal GDP

(38) $GDPVA_k = \sum_{i} [PVAB_{i,k} * X_{i,k} + PREM_{i,k}] + \sum_{c1} TARIFF_{k,c1} + INDTAX_k$

Real GDP

(39) $RGDP_k = \sum_{i} PQ_{i,k} * [CDD_{i,k} + GD_{i,k} + ID_{i,k}] + \sum_{i,c1} PWE_{i,k,c1} * E_{i,k,c1} * EXR_k - \sum_{i,c1} PWM_{i,k,c1} * M_{i,k,c1} * EXR_k$

Exports Equations and Productivity Externality Equations

CET Aggregation or aggregate domestic output for country k

(40) $X_{ie1,k} = AT_{ie1,k}[\gamma_{ie1,k} * EK_{ie1,k}^{-\rho_{ie1,k}} + (1-\gamma_{ie1,k}) * D_{ie1,k}^{-\rho_{ie1,k}}]^{-1/\rho_{ie1,k}}$

Export Demand of the Aggregate CET Export Sectors (ie) for Countries

(41) $EK_{ie1,k} = D_{ie1,k}[\frac{PDA_{ie1,k}}{PEK_{ie1,k}} * \frac{\gamma_{ie1,k}}{1-\gamma_{ie1,k}}]^{1/1+\upsilon_{ie1,k}}$

Export of Non-Export Sectors is Equal to Domestic Sales

(42) $X_{ien,k} = D_{ien,k}$

ROW Export Demand

(43) $EK_{i,k,row} = EKO_{i,k,row} * [\frac{PWE_{i,k,row}}{PWEO_{i,k,row}}]^{-etae_{i,k}}$

Trade Quantity Consistency

(44) $M_{i,c1,c2} = E_{i,c2,c1}$

Capital Good Imports

(45) $MKPTL_k = \sum_{icap,c1} PWMO_{icap,k,c1} * M_{icap,k,c1}$

Country Aggregate Exports

(46) $EKPTL_k = \sum_{c1,i} PWE_{i,k,c1} * E_{i,k,c1}$

Export Productivity Externality Parameter

(47) $SAD_{ie1,k} = (\frac{EK_{ie1,k}}{EKO_{ie1,k}})^{etae2_{ie1,k}}$

Intermediate Input Productivity Externality Parameter

(48) $SAD2_{i,k} = (\frac{MKPTL_k}{MKPTLO_k})^{etam2_k} * (1 - PVAB0_{i,k}) + PVAB0_{i,k}$

Capital Good Productivity Externality Parameter

(49) $SAC_k = (\frac{EKPTL_k}{EKPTLO_k})^{etak2_k}$

Import Demand Equations

Domestic Price of Imports

(50) $PM_{i,k,k} = PD_{i,k}$

Translog Price Index (Deaton & Muellbauer 1980)

(51) $\log(PQ_{i,k}) = AQ_{i,k} + \sum_{c2}(\alpha_{i,k,c2} * \log(PM_{i,k,c2})) + \frac{1}{2} * \sum_{c1,c2}(\gamma_{i,k,c1,c2} * \log(PM_{i,k,c1}) \quad \log(PM_{i,k,c2}))$

Import Value Share (Expenditure Share)

(52) $SMQ_{imi,k,c1} = \alpha_{imi,k,c1} + \beta_{imi,k,c1} * \log Q_{imi,k} + \sum_{c2} \gamma_{i,k,c1,c2} * \log(PM_{i,k,c2})$

Country Import Value Share Aggregation

(53) $SMQ_{i,k,k} = 1 - \sum_{c1} SMQ_{i,k,c1}$

Imports Demand

(54) $M_{i,k,c1} = \frac{SMQ_{i,k,c1} * PQ_{i,k} * Q_{i,k}}{PM_{i,k,c1}}$,

Domestic Price and Import Price Consistency

(55) $PD_{i,k} * D_{i,k} = SMQ_{i,k,k} * PQ_{i,k} * Q_{i,k}$

Pollution Equations

Sectoral Quantity of Pollution

(56) $QP_{i,k} = \theta_{i,k} * RGDP_{i,k}$

Sectoral Quantity by Pollutant

(57) $P_{i,k,p1} = \lambda_{i,k,p1} * QP_{i,k}$

Treatment Demand

(58) $T_{i,k,t1} = \omega_{i,k,t1} * P_{i,k,p1}$

Market Clearing Equations

Composite Domestic Final Demand

(59) $Q_{i,k} = INT_{i,k} + CDD_{i,k} + GD_{i,k} + ID_{i,k}$

Factor Demand Equilibrium Condition

(60) $FS_{f,k} = \dfrac{\sum FACTORS_{i,f}}{SAC_{f,k}}$

Average Wage with Current Weights

(61) $AVWF_{f,k} = \dfrac{\sum_i (1-ft_k)\quad WFDIST_{i,f,k} * WF_{f,k} * FACTORS_{i,f,k}}{\sum_j FACTORS_{j,f,k}}$

Foreign Savings

(62) $FSAV_{k,c1} = \sum_i PWM_{i,k,c1} * M_{i,k,c1} - \sum_i PWE_{i,k,c1} * E_{i,k,c1}$

Trade Balance Consistency

(63) $FBAL_k = \sum_{c1} FSAV_{k,c1}$

In the present model closure, it is assumed that the aggregated trade balance (*FBAL*) is fixed for each country and the exchange rate (*EXR*) varies to achieve external balance. Real investment (*ZFIX*) and government real consumption (*GDTOT*) are both assumed fixed at the base year. To satisfy the government budget constraint in equation 29, the model permits lump-sum government savings (*GOVSAV*) to be determined as a residual (government transfers to households and enterprises are both fixed). On the international market, borrowing by the government (*FBOR*), net foreign savings (*FSAV*), and foreign capital flows to enterprises (*FKAP*) are all fixed.