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Induced Institutional Change in the Trade and Environment Debate:
A Computable General Equilibium Application to NAFTA With Endogenous Regulation Setting

presented by

Heinz J. Jansen

has been accepted towards fulfillment of the requirements for

Ph.D. degree in Agricultural Economics

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INDUCED INSTITUTIONAL CHANGE IN THE TRADE AND ENVIRONMENT DEBATE: A COMPUTABLE GENERAL EQUILIBRIUM APPLICATION TO NAFTA WITH ENDOGENOUS REGULATION SETTING

By

Heinz J. Jansen

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment
of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1998

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ABSTRACT

INDUCED INSTITUTIONAL CHANGE IN THE TRADE AND ENVIRONMENT DEBATE: A COMPUTABLE GENERAL EQUILIBRIUM APPLICATION TO NAFTA WITH ENDOGENOUS REGULATION SETTING

By

Heinz J. Jansen

Because of the assumption of constant emission factors, economy-environment models often show that free trade has negative environmental consequences. However, this pessimistic view ignores the possibility of trade strengthening the demand for regulatory institutions. An "institutional optimism hypothesis", stating that the net environmental result of trade liberalization is benign, is thus formulated in this paper. The hypothesis can be understood as application of the "environmental Kuznets curve" to a trade context. The hypothesis is examined with a specially developed CGE model that allows decomposing the environmental influence of economic policies into growth effect, allocation effect, composition effect and regulation effect. The latter is achieved by treating institutional change as an endogenous process dependent on income. Application of the CGE model to NAFTA, using a broad range of scenarios, supports the institutional optimism hypothesis. The net pollution effect of trade liberalization is beneficial or insignificant, even for the country specializing in polluting industries. The implication is that in many cases environmental interests are served better by a focus on institution building in trading partners, than on the process of trade liberalization itself.

The dissertation is organized in six chapters. Chapter 1 reviews the literature on trade and the environment; Chapter 2 develops the institutional optimism hypothesis in a simple theoretical model; Chapter 3 describes the CGE model designed to empirically examine the research question; Chapter 4 describes the model calibration; Chapter 5 presents the simulation results; and Chapter 6 concludes.

To Daniel

ACKNOWLEDGEMENTS

"Though I am suspicious of CGE models, I am very fond of CGE modelers. It must be that the process of model building and calibration leave in their wake a great deal of understanding about how real economies function". (Edward E. Leamer, 1993).

The learning experience of writing this dissertation lasted substantially longer than I anticipated. In particular, after I started my job at the European Commission four years ago, the completion of the dissertation was often a strain.

Numerous people contributed in their own way to its completion. The longest-lasting encouragement comes from my parents who always inspired me to follow an academic path. More than anyone, my parents wanted to see me complete my studies, thus providing the important impetus of giving me a bad conscience about procrastinating. I thank them for their love and support.

Undoubtedly, I owe most to my wonderful friend and wife Wanda who suffered with me all the way. Her love, patience, and encouragement made life in the all-but-dissertation limbo endurable; her proofreading skills helped to substantially speed-up and improve my writing; and finally she put things into perspective by giving birth to our son Daniel (sometime during the first draft of Chapter 4), whose broad smile makes this dissertation appear insignificant.

I am grateful to my boss and friend, Manfred Bergmann, for holding my back free so that I could finally move this paper to completion from its everlasting near-finished status.

Academically, I am indebted to the members of my dissertation committee: Charley Ballard, Sandra Batie, John Hoehn and Tom Reardon. Ted Tomasi provided guidance and financial assistance, before his departure from Michigan State University. My committee members made the long-distance completion of this paper as smooth as possible, and willingly accepted printing out hundreds of pages sent to them by e-mail. All provided thoughtful critical comments. I am especially indebted to Charley who guided me though the long process of completing the CGE model. Finally, I owe my gratitude to Tom for being my committee chair who guided me wisely and swiftly through the final stages of the process.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1. Introduction

The increasing globalization of the world's economies has resulted in recent years in a sharp rise in interest in the interaction between international trade, environmental quality and pollution. Several international bodies have reacted to the political pressure and the recognition that trade might have a negative impact on the environmental situation in various countries. Notably, the newly established World Trade Organization (WTO) has established a committee to study trade and environment issues. Similarly, the OECD and the UNCTAD have set up study groups to review the relationship between trade and environment. Rarely has this problem entered the political debate more forcefully than in the context of the North American Free Trade Agreement (NAFTA). NAFTA brought to the forefront of discussion the environmental effects of trade due to unequal economic development and regulatory standards of the nations involved. The opening of borders was feared to turn the Mexico into a pollution haven that erodes American environmental standards.

The number of articles published in the last few years on the environmental aspects of NAFTA, or on trade and environment in general, certainly goes into the hundreds. It will therefore be difficult to provide any substantive new argument to the debate that has not been made somewhere. Despite the richness in argumentative material, however, there is a surprising lack of quantitative information on the various factors that shape the environment and trade interaction. This missing information on the relative importance of the economy-environment interactions is matched by a lack of coherence in the theoretical conclusions on what to expect when trade barriers are removed.

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This paper will advance the discussion in several ways. A first contribution will be to sort the mechanisms and arguments. Other authors have provided literature reviews before. Here the approach will have the sole focus of what happens when countries with different environmental standards engage in trade. This approach allows the organization of the existing literature around two empirically testable hypotheses: the traditional pessimism hypothesis and the poverty attraction hypothesis. The traditional pessimism hypothesis has two parts. Its first part, the industrial flight hypothesis, predicts that polluting industries end up in the countries with the most lax environmental regulation. Its second part, the pollution haven hypothesis, states that countries use this mechanism to relax environmental standards to attract industries. The poverty attraction hypothesis states that underdeveloped countries have a comparative advantage in polluting industries, which they cannot strictly regulate. Under these two hypotheses trade would likely to be bad for the environment.

The second contribution of this paper is the formulation of a counter hypothesis to the poverty attraction hypothesis, which we call the institutional optimism hypothesis. Its starting point in contrast to the other two hypotheses is that the regulation stringency of a country cannot be treated as a *ceteris paribus* condition. By making poor countries wealthier, trade contributes to increasing the countries' capacity and willingness to improve its environment. This tendency will in many cases outweigh the effect of any shift in the location of polluting industry. This hypothesis will be illustrated in a simple theoretical model.

The third contribution of this paper is the empirical test of all three hypotheses in a computable general equilibrium model of the North American Free Trade Agreement. The interest of this paper goes beyond that of the narrow goal of only analyzing the trade-environment relationship of the NAFTA. Due to the large differences in the economic developm

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development between the USA and Canada on the one side and Mexico on the other, the case of NAFTA can also be seen as a microcosm of the forces at work in North/South trade liberalization in general. Therefore, the present paper understands the analysis of NAFTA as a case study of a more general phenomenon, where it takes advantage of the fact that this case is probably better documented than any other case of trade liberalization between trading partners of such unequal development levels.

The computable general equilibrium (CGE) tool, which is developed in this paper to analyze trade and environment interactions, incorporates a number of components that other models have neglected. In particular, (i) it fully incorporates a pollution externality, which is both necessary to gain a correct welfare assessment and the production feedback of environmental policy. (ii) It is a three country model, which allows testing as to whether there are systematic differences between Northern and Southern countries, to test the poverty attraction hypothesis. (iii) It treats the regulation levels as endogenous. This feature allows the analysis of the institutional optimism hypothesis. (iv) It provides a full disaggregation of the various effects of trade on the environment. Other authors focus on aggregate numbers which tend to give faulty impressions.

The empirical results show that (at least for local pollutants), the net result of trade liberalization is an environmental improvement. Therefore, in general, trade is good for the environment, even where large regulatory differences exist.

The remainder of this introductory chapter further motivate the arguments just sketched. To this end it will first position the empirical questions with the remainder of the trade and environment literature. It will then briefly discuss some methodological preliminaries. After this it will go on to

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Chapter 2

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it will go on to discussing the theoretical and empirical literature on the traditional pessimism and the poverty attraction hypothesis.

Chapter 2 formulates the institutional optimism hypothesis. This idea is developed in a simple theoretical model that incorporates an endogenous policy formation process into the analysis of trade-environment relationships. The system of equations in the computable general equilibrium model for the empirical testing is shown in Chapter 3. Chapter 4 describes the data set and calibration of the model to NAFTA. Chapter 5 presents various simulation runs. Chapter 6 provides a summary and concluding remarks.

1.2. Position of this Dissertation within the Trade and Environment Literature

The present paper focuses on assessing the economic interactions between environmental regulation and the pattern of trade. The issue can be divided into two sub-problems. First, there is the question of what effect a given differential in environmental stringency has on the trade specialization of countries. This effect will be important in determining the degree to which trade liberalization results in an improvement or a deterioration of the environmental situation of the affected countries. The following chapter will provide an overview over the abundant theoretical literature and the more scarce empirical literature on this aspect.

Second, trade liberalization directly and (mostly) indirectly influences the level of regulatory stringency of countries, as it shapes both the economy and society of a country. Chapter 2 will attempt to shed some light on this issue and develop a simple but instructive model that shows that the internalization of the regulatory standards can fundamentally alter the findings of standard models.

The twin questions of how trade influences the environment and how regulation influences trade does not exhaust the literature that can be found under the "trade and environment" label. At least five further topics exist, which will not be addressed in this paper:

1. Ethical aspects of trade and environment

Probably the most important driver of the environmental component of the NAFTA debate was the emotional and political argument that free trade erodes the national sovereignty in setting environmental standards (Shrybman 1990)[1]. Hostility against free trade was focused especially through the notorious tuna-dolphin case. The United States imposed an embargo against the import of Mexican tuna fish caught with purse-seine nets, which kill dolphins in a greater number than U.S. law permits (Audley 1993,). The GATT (General Agreement on Tariffs and Trade) Dispute Settlement Panel ruled that the import ban violated the international trade code on grounds that regulating the production process of a good falls under the jurisdiction of the producing country only.[2] The importing country has no right to impose its particular environmental preferences for production processes on another country (Arden-Clarke 1992b). The Standards Code of the GATT does, however, allow a country to impose import restrictions on goods which do not meet national product standards, such as certain chemicals, pharmaceuticals, and wastes. On a multilateral level, examples of this kind are the

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[1] In this context, it has been proposed to use the term "deregulated trade" over the more emotionally positive expression "free trade" (Daly 1993).

2 The panel has a point in stating that environmental restrictions should in principle not be treated differently from differences in labor and capital use among countries. However, it evidently did not take into consideration that both Mexican and U.S. companies fish in the same body of water, rather than within their national waters. Because every tuna fish harvested by Mexicans can no longer be fished by American fishers, the case should have been treated like a transboundary externality.

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Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)(Stevens 1993, GATT 1992).

In light of these concerns, amendments to the original NAFTA treaty have been made. Political pressure led to an inclusion of side agreements about environmental standards that allow for heavy fines and even possible trade sanctions, if national trade laws are not enforced. An overview of the agreements is provided by Hufbauer and Schott (1993, p. 159f). There exists, however, some agreement that the NAFTA side agreements are designed mainly to pacify environmental interests, with limited practical implications (Audley 1993). Additionally, a U.S. court ordered to undertake an "Environmental Impact Statement" of the North American Free Trade Agreement (Wall Street Journal, 1 July 1993; Hufbauer and Schott 1993, p.159).

While the ethical considerations of trade liberalization certainly merit attention, in particular insofar as they affect countries with substantially differing pollution standards, they have already been spelled out in other places (e.g., Bhagwati 1993, Daly 1993). This paper will concentrate on the narrower economic issues involved.

2. Trade as a policy instrument to entice environmental behavior in other countries

Related to the first issue, there exists a link between trade and environment in the political sense that it has been proposed to use trade sanctions as a means of pushing countries with lax environmental regulations into complying with stricter standards (Anderson 1995). The link between trade and the environment can be seen as analogous to that between trade and human rights issues. There is no pretext of a causality. Trade policy (such as the refusal to grant most favored nation status) is used only for want of a better leverage point on the achievement of a policy goal. This political aspect will also be neglected in the present paper.

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3. Instruments for safeguarding international or unilateral environmental actions

Of a different nature and more focused on environmental issues are questions of how to assure that unilateral or international environmental policies are not undermined through trade. For several tools, theoretical research and practical applications can be found. First, there are various schemes to introduce environmental labelling (e.g., Jha, Vossenenaar, and Zarilli 1993; UNCTAD 1995, OECD 1997a). This approach means that environmentally friendly products (produced at home and abroad) can obtain a label that informs consumers about the environmental standards applied in its production process. These consumer awareness schemes exert a certain pressure on producers to apply clean technologies. Second, in accordance with the WTO treaty, signatories to international environmental agreements can limit trade on the product in question (OECD 1997b). Third, there exists a (mostly theoretical) literature on border tax adjustments, i.e. a compensation both for imports and exports for differences in environmental taxes. (Mani 1996, Scherp and Suardi 1997).

4. Trade in hazardous waste

There exists a broad array of literature on trade with hazardous products (see for instance: Hackmann 1994; Kummer 1994). While this is an interesting economic topic in its own right, the present paper focuses on the influence of environmental regulation on the broad economy, not on a narrow set of individual products. In practice, this exclusion means that pollution is only considered insofar as it affects the production process of those goods that are otherwise not considered harmful. The trade in hazardous waste is therefore ignored.

5. Design of optimal policies in an open economy

Game theory is one of the most fruitful areas of theoretical research in the field of trade and environment. There exist numerous models looking at the policy outcome when the trade and enviro

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and environmental policy in one country is not seen as independent from the policies of other countries. Variations of these models include the type of externality (local, cross-border, global), market structures (monopoly, oligopoly, duopoly, atomistic), types of behaviour (perfect competition, Nash, Bertrand competition), the number of countries involved (two or more), etc. However, very few papers of this type attempt any quantification of these interactive aspects. At best, they tend to be limited to numerical examples of their theoretical models. As our focus is more of an applied nature, rather than one of (optimal) policy design, this literature is also largely ignored. As it would be difficult to provide a brief review of the literature in the field, the reader is referred to Ulph (1994).

1.3. Key Concepts for Understanding the Trade and Environment Interaction

The task of reviewing the literature is facilitated through the fact that the dispute between proponents and opponents of free trade, in light of differing environmental regulations, is not a dispute over methodological issues. Both sides use similar economic models and largely agree on the relevant mechanism that trade liberalization will induce. The starting point is that trade will change the structure of the economy. Some sectors will suffer under the burden of new competition, some industries will relocate into the country that gives them a competitive advantage. Labor-intensive industries might have an incentive to relocate to the country with lower wage rates (in this case, Mexico). This could be because of lax environmental regulations or other factors, such as low labor cost. Other sectors will benefit from the enlarged markets. Others may resettle, because they seek lax environmental regulations. On the other hand, some ir

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hand, some industries in the wealthier country (United States[3]) will expand because they have a comparative advantage over their Mexican counterparts, or simply because a richer Mexico is able to buy more products from the U.S. The dispute about what the net effect of these changes on economic welfare and the environment are, lies in different beliefs about the respective magnitudes of the likely changes (as well as in differences in the willingness to accept consequent sectoral and regional redistribution of economic activities).

To disentangle the various effects of trade liberalization on the environment, the following taxonomy is useful:

1.3.1. Taxonomy of Trade Effects Influencing the Environment

Grossman and Krueger (1995) have disaggregated the economic changes that affect the environmental quality into three components, the scale effect, the composition effect, and the technique effect.[4]

Scale Effect: If trade increases the size of an economy without changing anything else, the resource use and pollution level will increase by the same proportion. The intuition behind the scale effect is simple. If, for example, twice as many vehicles drive on the roads, fossil fuel emission will double, too. If trade therefore increases the national income, *ceteris paribus* the effect on the environment is deleterious.

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3 Because of the relatively minor role of the Canada-Mexico interaction and the relative similarity between the Canadian and United States economy, the following discussion treats NAFTA as a bilateral treaty between Mexico and the U.S. In general, the arguments concerning the situation of the United States are equally valid for Canada.

4 Compare also Stevens (1993).

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Composition Effect: The conclusion of the previous paragraph is only valid if the composition of the economy does not change. Within the economy, the distribution of costs and benefits of free trade is uneven. If the expanding sectors are relatively pollution-intensive while the contracting ones are non-polluting, the scale effect will be reinforced. In the reverse case, the composition effect works to reduce the pollution level, and may potentially outweigh the scale effect.

Technique Effect: The composition effect again provides additional information only about output changes of the economy. Change in the environmental intensity of production can, however, also be the result of changing techniques used in the production processes. The World Development Report 1992 (World Bank 1992, p. 39) decomposes the technique effect further into two components. First, an increase in the input-output efficiency reduces the demand for resource inputs. Secondly, polluting inputs can be substituted with more environmentally benign inputs. Modifications in the production technique are the third important linkage through which trade can change the quality of the environment. Of the three effects, this technique effect is the least understood, and the most difficult to model analytically. Beyond the assertion of certain elasticities of substitution between factor inputs as prices change, economic theory still does a poor job of explaining what induces technical change.

In altering the scale, the composition, or the production technique of an economy, trade policy is environmentally relevant. The pathways through which these alterations takes place are many, and usually concern more than one of these three effects. Fundamentally, the dispute between proponents and opponents of trade liberalization lies in different beliefs about the respective magnitudes of the likely changes, as well as in differences in the willingness to accept the consequent sectoral and regional redistribution of economic activities and their environmental

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environmental consequences. Because there is a lack of studies that quantify the magnitude of the effects involved, positions in the discussion are based largely on faith, a rift that goes right through the environmental movement itself. While the issue can (at least in principle) be settled through empirical analysis, emotional issues accompany these disputes and go beyond the scope of a narrow economic analysis.

1.3.2. Environmental Endowment

As a second preliminary, it is necessary to define the economic concept of "endowment" as it is used in the following review of the trade literature. The literal interpretation of the term would simply mean the number of units of a given factor that is available to the economy at the beginning of the analysis. For the purposes of the trade literature, the term needs to be interpreted more loosely in two important aspects. First, endowment is an aggregation of sub-units of different qualities. Without actually bothering about the theoretical complexities involved in the economic aggregation, it should be understood that the concept denotes simply a vague description of relative availability of a certain class of input factors. Second, practically no factor is really fixed in its supply. Given the right incentives, the availability of any factor--for production purposes-- can be increased. People can change the amount they work, plow more land, and so forth.

Natural endowment in the way it is used here is therefore not identical with the natural assimilative capacity, i.e., the ability of the environment to absorb pollutants or to provide raw materials for production. Availability of resources for production results from the interactions of demand for assimilative services, and from the public preferences and institutional settings that make them accessible (Blackhurst 1977).

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The concept of environmental endowment and of the pollution-intensity of a good are amorphous, as production may affect a wide number of environmental media to a varying extent. They should be understood here in the broad theoretical sense of general availability and use of the environmental medium (Leonard 1988). The treatment of environment in economic modeling can be as understood analogous to that of labor, which is also the aggregation components that differ in qualities like skills and training.

The absorptive capacity of the environment is only the ceiling to the use of environmental inputs. This limit is usually only reached under duress, in the same way that people usually don't work all hours they are awake. In both cases, the ceiling can be exceeded only at the cost of collapse, and is effectively binding.[5] The usual amount of both labor and environment that is used in production falls below this theoretical extreme, and people keep leisure time as well as certain environmental factors out of production.

The availability of environment is the result of economically and institutionally determined artificial scarcity and demand for assimilative services that result from consumption, production, and technology. Environmental availability is similar to the supply of labor, which is not simply a linear function of the population, but depends on wage rates, individual preferences, and cultural and structural idiosyncrasies of countries that may keep certain groups like women and minorities from working, or may force some to work against their wills.

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[5] Under extreme circumstances, they may be exceeded over a short period of time, but in both cases their future production potential will be reduced.

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In the same way that changes in wages can alter the supply of labor in an economy, the availability of environment also varies with changes in the opportunity cost of resources. The actual physical availability of environment is therefore relevant for the composition of the economy and the determination of trade patterns only insofar as it influences the political and institutional availability of environment for the production process. Factor endowment does not denote the maximum theoretical level of availability of environment or labor-capital, but the quantity used in equilibrium. It is in this sense that Mexico, for instance, could be called resource abundant, because it is relatively cheaper and easier to pollute here than in the United States, because regulations and enforcement are relatively lax. If one looks only at the magnitude of resources per capita, one would come to the opposite conclusion that Mexico is resource-scarce compared with the United States. Relative environmental abundance in the U.S. has, however, been turned into relative scarcity, through the force of the law that sets tighter environmental standards for American producers than those their Mexican counterparts face.

There exist a variety of mechanisms through which the supply of environmental resources may be restricted. This restriction could be achieved through regulatory instruments that are enforced by the government, or through a sale of the rights to exploit the resources, either from private owners or a state agency. The same level of environmental quality can be attained using either quality standards or monetary instruments such as taxes or emission permits. As most of the models in the following discussion abstract from transactions costs and pay no attention to the distributional consequences of different regulations, no distinction of the type of instruments is necessary. The implicit price of regulatory instruments could be translated into the explicit price that results from a limitation of the endowment through emission perm

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emission permits issued by the state. It is therefore easiest to understand price as the explicit market value of these tradable permits to avoid the complex rhetoric of interpreting the price of a resource as its shadow productivity (i.e., the increased output that would have resulted from an incremental increase in its use).

In the following discussion, environmental regulation is to be understood only as those measures that enterprises actually have to undertake. This requirement need not be identical with the letter of the law. Many countries have very strict regulations on the books which are not enforced in practice, either through corruption, lack of enforcement tools, or a political bargaining process. National or local governments may grant exemptions from, or carry the costs, of environmental regulations in order to attract investments, so the environmental constraint is not binding that for the firms. In other cases, the *de facto* constraints may exceed legal constraints, as social pressures can block certain types of investment that are perceived as risky, such as waste dumps and power plants (Leonard 1988, 65). Whatever is the cause of limiting the use of environmental functions for the economic process, for the following discussion, a restricted availability is interpreted as economically equivalent to a limited endowment. Unless explicitly stated, the discussion will also neglect any reduction in environmental externalities. This means that environmental policies always imply increase costs.

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1.4. Traditional Pessimism Hypothesis of Trade and Environment

The complexity of the interactions between trade and the environment finds its expression in a considerable and rapidly growing body of literature[6]. An exact theoretical prediction of the net effect of trade liberalization on the level of pollution is difficult, because there are usually a number of counteracting mechanisms at work. Since the level of complexity in an economic analysis rises rapidly with the inclusion of additional elements, there is no work in the theoretical literature on trade and the environment that attempts to incorporate all relevant interactions between the environment and the economy. Rather, most papers focus on one or two important aspects that could be brought forward by a trade liberalization. In a later section we will report on what empirical literature there is to corroborate the theoretical findings.

1.4.1. Environment and Comparative Advantage

The simplest modelling approach in the literature is based on the classical Heckscher-Ohlin model with two countries, two goods, and two factors. Environment simply serves as one input factor while the other factor is a composite good, consisting of labor and capital (Ohlin 1935). Under a number of special conditions (perfect competition, zero transportation costs, incomplete specialization, identical linearly homogenous production functions, identical homothetic preferences, absence of external economies, constant relative factor intensities at all relative factor prices, factors homogeneous in quality, and the number of factors no greater than the number of commodities), the three basic theorems of international trade can be derived.

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[6] An earlier review of the literature has been undertaken by Dean (1992).

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The first is the factor price equalization theorem. It states the basic interaction between output and input prices in an open economy. In a situation of autarky (i.e., in the absence of trade) output prices in the two countries will generally differ, reflecting the different scarcities of the input factors. In a country that is relatively abundant in environmental resources, a good that is resource-intensive will be relatively cheaper than in a country where resources are scarce compared with labor and capital. Similarly the input factors will be more expensive in a country where they are scarce than where they are abundant, reflecting their decreasing marginal productivity.

As trade barriers are removed, the prices of the traded goods are equalized across the countries. The factor price equalization theorem now states that, under the above listed set of assumptions, the factor prices will also be equal in the two countries, even when the factors are immobile between them. Factor prices are a function of output prices only. With this equalization of both output and input prices established, the standard result of trade theory follows automatically: A country exports goods that are intensive in the use of the factor with which the country is well endowed. A resource-abundant country therefore exports resource intensive goods, and imports goods that are intensive in the use of capital and labor. In the jargon of trade theory, a resource-abundant country has a comparative advantage in producing pollution-intensive goods.

The Stolper-Samuelson theorem states the direction in which factor intensities move when the relative output prices change, be this as a result of trade liberalization or a shift in the demand curve (Stolper and Samuelson 1941). An increase in the relative price of the environmentally intensive good raises the demand for environment as an input factor and with it, its price. An adjustment process takes place that equalizes marginal productivity to the new price l

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price levels. This adjustment means a substitution away from the more expensive environmental input towards the now cheaper capital and labor input. This substitution is taking place in both industries so that they will both be less resource-intensive than before. However, the overall use of resources will not fall, because the share of the resource-intensive good in the overall output increases. Obviously, the same process takes place with opposite signs if the original change is a drop in the price of the resource intensive good.

The third important theorem of trade is the Rybczynski (1955) theorem. It deals with the question of what happens if one of the endowments of a country changes. An increase in the availability of natural resources brings the intuitive result that production of the environmentally intensive good will expand. Less intuitively, but as a direct result of the above listed assumptions, the production of the capital and labor intensive good shrinks. If the country is previously a net exporter of the pollution-intensive good, its exports will rise further, as will its imports. If the country is an importer of the pollution intensive good, the good will be substituted for by home production and the trade volume will drop. The Rybczynski theorem means therefore that specialization increases as the differences in endowments between countries become larger. A country that sets strict emission standards therefore exports its pollution problem via trade. Conversely, in an open economy other countries share the benefits of increased output that may result from lax emission standards.

The three theorems that result from the Heckscher-Ohlin model are based on quite restrictive assumptions. However, the framework has served as a starting point for much of the theoretical literature on trade and environment. Next to the elegance of the model, its attractiveness lies in the modeling assumptions themselves, which make initial factor endowments carry the entire burden of the explanation of trade patterns. If environment is simply

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simply interpreted as if it is also a factor endowment, the effects of a change in policy can be interpreted in a straightforward manner. Most models, however, have moved beyond this two-commodity, two-factor, two-country world that forms the core of classical trade theory.

In the following review, it is mostly assumed that trade takes place between two stylized countries with unequal endowments, because the political concern about the environment-trade interaction is centered around asymmetric alliances, such as those between the USA and Mexico, between Europe's North and South, or between OECD countries and the Third World. One country is therefore presumed to be rich and well-endowed with capital, but relatively scarce in labor and in environmental endowment, reflecting its comparatively strict pollution regulations. The other country is taken to represent a prototype of a Third World country, with little capital, many working hands, and lax environmental regulations. Although this caricature of a trade agreement is not strictly needed for the theoretical analysis it is useful in focussing the discussion on the cases most relevant to the problem.

Although it is not strictly an environmental paper, Jones (1971) provides an important early contribution to the issue, by presenting an analysis of the Heckscher-Ohlin framework with three instead of two input factors. In his analysis, only labor can be used for the production of both outputs, while capital is only used for one good, and land (environment) is used exclusively for the production of the other output. An important conclusion of his analysis is that the factor price adjustment mechanism need not hold true. This conclusion means that factor prices are not uniquely determined by the price level of outputs, but also by the general availability of factors within an individual country. Even in a trade equilibrium with equal prices for goods, the rewards for factors between two countries can differ. A greater supply of environmental goods thus can entail an increase in the compensation for other factors.

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It is consistent with Jones's model that the return to both labor and capital was throughout history persistently higher in the United States than in Britain, as the US had a greater abundance of natural resources, especially land. Under the assumptions of Jones' model, government policies that regulate the availability of environmental inputs thus affect directly the wage rate and interest rate of a country. Jones shows that this seemingly minor generalization of the Heckscher-Ohlin model leads potentially to different policy conclusions. For a small country in the Heckscher-Ohlin model, the reward for one input stays unaffected by changes in the supply of the other input. It is of no significance for owners of inputs, if they live in a country with resource abundance or not. Due to its limitation in the movement of factors between sectors, Jones's model produces the result that it very well matters for the return on labor and capital what environmental regime rules the availability of resources. Capitalists' and workers' incomes depend here on the restrictiveness of environmental policy.

It should be noted here that usually the factor returns do not react in a symmetrical way. The extent to which a certain factor benefits from a decrease in the price of the natural resource is positively related to two economic parameters, namely the factor intensities and the elasticities of substitution: If the goods that are intensive in the use of environmental inputs are also relatively intensive in labor inputs, labor will overproportionally profit from lower resource prices. In addition, a great elasticity of substitution between labor and environment (compared to that between capital and environment) will benefit labor. The higher this elasticity difference is, the more labor flows towards the resource-using sector in order to equalize productivity of resources among sectors. Movement of labor out of the capital-using sector lowers the productivity of capital. In the extreme case, the net return to capital may even fall, depending on the model parameters. The reverse case can be made analogously. The ambivalence in the net results in Jones' model stresses the fundamental importance of having good empirical estimates of input substitution possibilities and factor intensities, in order to avoid qualitative errors in the analysis.

McGuire (1982) shows that factor-price equalization breaks down as countries implement different environmental regulations, which he models as neutral technical regress. Regulatory differences violate the condition of identical technologies in the standard model. In contrast to Jones, however, in McGuire's model the reward for the factor used intensively in the non-regulated industry will increase unambiguously. While giving clear proof of the possibility of deviations from the factor-price-equalization theorem, the use of Jones' and McGuire's analysis for policy conclusions has limitations in that the analysis takes important parameters as externally given even though these parameters are really influenced by the policy itself. One critical assumption is that output prices are not influenced by domestic policy. In the case of NAFTA or the European Union, for at least some sectors, the assumption cannot hold that price levels will remain unaffected by changes in the national environmental policies. Of course, the degree to which competitiveness is changed depends not simply on the permissible emissions but also on the type of environmental policies chosen. For instance, an industry might be more sensitive to a tax instrument than to a regulation. Clearly, however, insofar as environmental policies alter the competitive position of an economic sector of a country, the analysis will have to include effects on the balance of payments and the terms of trade.

Furthermore, as factor rewards change, factors supplies generally also change. Demand growth for a pollution-intensive good raises the productive value of pollution. Consequently pollution tends to rise. The assumption of fixed factor supply in the Heckscher-Ohlin model, however, implies that changing price levels do not affect the level of environmental quality of a count

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country. A step towards incorporating demand and factor supply effects is undertaken in the analysis of Baumol and Oates (1988).

The authors consider a model that is based on the aggregation of the supply and demand curves of two trading countries. Assume that a country induces an upward shift in the supply curve of its pollution intensive good by imposing stricter environmental regulations. This increases the global price level of the polluting good, and reduces the quantity consumed. Obviously, the pollution level in the home country will be reduced. The proposition by Baumol and Oates that the global pollution level must fall, however, seems to hold unambiguously only under the limiting assumption that the country that increases the regulatory stringency has more lax regulations than the other country. It is conceivable, however, that in some sectors an increase in the environmental standards of the more regulated country leads to an increase in overall pollution emissions, if it induces an increase in pollution-intensive production in the country with the less stringent regulation. It would be straightforward to construct a modified version of the Baumol and Oates model that produces this result.

In the model, the balance-of-payments effect on environmental regulation depends on the question of whether the regulating economy is a net importer or exporter of the pollution-intensive good. For importing countries the balance of payments will deteriorate as home production falls and the price level of imports increases. For exporters, decreases in home production and price increases point in opposite directions. The direction of balance-of-payments changes is therefore not clear *a priori*. Also, whether non-environmental factors benefit or suffer under regulatory policies will depend on the shape of the demand curve. A low price elasticity of demand can mean that the return to labor and capital actually rises, as the sector extracts a quasi-monopoly rent from its price increase.

In the same way as the Jones model cautions us to consider the importance of input substitution elasticities in deriving qualitative results, the Baumol-Oates model stresses the sensitivity of modelling to demand elasticities. The sensitivity of the result to elasticities may be even furthered by the omission in both models of substitutions in demand between differently polluting goods. If the government regulates one sector only, the pollution level may actually rise (even within a country) as the pollution reduction in one sector may be overcompensated by the pollution increase in another sector.

1.4.2. Factor Mobility and the Industrial Flight Hypothesis

The results presented are based on models that use the critical assumption that factors of production are internationally immobile. In most cases, such as the European Union and NAFTA, the assumption of capital immobility is, however, unrealistic. Mundell (1957) has shown that movements in factors can substitute for the movement in commodities and lead to an identical price-equalization phenomenon as in the Heckscher-Ohlin framework. In a two-factor/two-good world, the mobility of only one factor is needed to produce the result. If capital is the mobile factor, it would move into the capital-scarce country until factor-price equalization is reached. The capital-abundant country loses production, while the labor-abundant country increases overall production. As a firm has the choice of either serving a foreign market through exports or through production in the foreign market, capital flows in general will reduce the level of trade between countries, although it is possible that investment and trade are supplements (Markusen 1983; Wong 1986).

McGuire (1982) demonstrates that, in a Heckscher-Ohlin type model, the regulated industry will be completely driven out of the regulating country. If the factor that is used intensively in the regulated sector is internationally mobile, it will migrate out of the regulating countr

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country and the overall economy will shrink, not only due to the decreased productivity entailed in the regulation, but also due to the loss in the production factor. If, however, the mobile factor benefits from the regulation, because it is not used intensively, a regulation can actually induce a factor inflow into the regulating economy. Although one would expect the first case to be the standard scenario, an economy could actually gain under a certain set of economic parameters.

Merrifield (1988) also provides an example of a model of pollution abatement with mobile capital. A tax on the polluting industries could actually increase pollution, because capital flows into the other country, and the consequent increase in pollution there may more than offset the reduction in emissions at home. The effect depends crucially on the elasticities of substitution among factor inputs, pollution and capital intensities in production functions, and the sensitivity of the capital stock to pollution damage within each country. Given the appropriate parameters, the model of Merrifield is thus capable of producing the nightmare scenario for rich countries: An increase in standards produces a loss of jobs while pollution increases.

Worries of trade unions and many environmentalists in wealthy countries about trade liberalization with poorer nations are based exactly on this reasoning of the mixed commodity-factor flow model. Of the three factors of production that we consider, poorer countries can be assumed to have an abundance in the two that are immobile (resources and labor), while they have a scarcity in the mobile factor (capital). To equalize factor rewards, capital will therefore move from the rich country to the poor where it is scarce, and hence earns a larger return. In the extreme, the poorer economy grows and the wealthier economy shrinks due to the capital flows.

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In the aseptic world of Heckscher-Ohlin models, there is no tragedy in the loss of production as the population of the country with capital outflow gets overcompensated for their loss through the higher rent they obtain in the foreign market. In real life there is, of course, the problem that capital owners and workers are not identical. A move of capital outside of a country implies direct job or earning loss and depresses the home country's (Keynesian) economic multiplier and its tax base. The ramifications of the standard model with capital mobility leave policymakers only the choice of taking a wage loss or of harmonizing the environmental standards.

There are a number of reasons, however, why the capital mobility model need not lead to an exodus of capital into the country that offers low wages and environmental costs. One important factor is that a firm's decision to relocate depends on more parameters than the three factors listed. Notably, the model neglects that labor is hardly homogenous. Know-how and human capital are often more important for a production process than the number of working hands. While most poor countries are surely well-endowed with unskilled labor, this condition is generally accompanied by a relative scarcity of skilled workers. For many firms, this scarcity is the decisive constraint not to relocate. Other factors, such as cultural barriers, political stability, quality of public infrastructure and communications firms, bureaucratic idiosyncracies, or even the low level of environmental quality, may be important factors that combine to create an industrial inertia that keeps companies from writing off the physical and human capital of existing companies in the home country.

The value of low environmental regulations in the host country also may be overrated as a factor for industrial location, since companies plan their pollution standards to meet standards that apply for the life span of the investment. As retrofitting of old equipment tends to be very expensive,

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expensive, firms will mostly orient themselves to meet expected regulations.[7] Often governmental rhetoric and anecdotal evidence point towards an increased stringency of environmental regulations. Even in the absence of regulatory enforcement, large international companies generally try to meet global environmental standards. Leonard (1988) points out in this context that many countries tend to apply stricter environmental standards to foreign rather than to domestic firms. These general remarks do not imply that there are no companies that relocate for purely environmental reasons as the theory would predict, but rather that their economic importance tends to be limited. By the same token high investment costs can act as a barrier to entry for new firms, which also cannot be measures directly.

The theoretical importance of capital flows is also dependent on differences in productivity between the country of origin and the receiving country. Capital flows and flows of know-how are usually tied to each other. If investment flows affect productivity in the poorer country, and with it the purchasing power, it may actually be increasing rather than decreasing trade and the wage rate--even for unskilled labor--in the richer country. In the framework of a simple model, Wong (1986) lists the necessary conditions for this. The positive feedbacks from productivity improvement may thus to a considerable extent benefit the richer country's trade flow, not least because international transplants tend to have a larger import share than domestic firms.

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[7] For chemical firms, Monty states that the capital investment necessary for pollution reduction on existing plants is roughly five times as expensive as the equivalent equipment installation in a new plant (Monty 1991, p.7).

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Despite the acknowledgement in the theoretical literature that capital mobility can critically alter the qualitative results of trade liberalization, an appropriate numerical modeling of capital flows is very difficult. The omission of the problem in most applied models has been lamented by several authors (Srinivasan and Whalley 1986, Goulder and Eichengreen 1992).

The preceding review of the literature presents the traditional arguments of how different levels of environmental regulation shape the pattern of trade specialization. This argument can be formulated as the "industrial flight hypothesis". It maintains that high pollution-control costs is a fundamental factor in making firms leave nations which have a high level of environmental regulations. Evidently, the link between pollution control costs and actual emissions will depend on the type of environmental policy in place.

1.4.3. Empirical Findings on Industrial Flight Hypothesis

Empirical studies on industrial flight hypothesis have to cope with the intrinsic difficulty of measuring levels of pollution and pollution control expenditures. Tackling these severe data limitations has produced a wide array of empirical methods. Different approaches range from the merely descriptive, to econometric tests and simulation models.

Kalt (1988) analyzes US trade flows from 1967 to 1977 in a cross-country regression. His findings point to an insignificant impact of environmental regulation on all sectors. However, if the analysis is limited to the manufacturing, a clear negative impact on exports due to regulation is established. This impact becomes even more significant, if the chemical sector is excluded from the manufacturing aggregate.

In analyzing the pollution content of trade flows, Robison (1988) finds that increases in pollution control have shifted the comparative advantage of the United States with Canada. More high-abatement-cost goods are imported and more low-abatement cost goods are exportec

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exported. While there is no doubt about this trend, the value of the study needs to be discounted on the grounds that it has the implicit assumption that standards remained unchanged in Canada. Furthermore, the analysis could be potentially biased by the timing of the years for which the abatement content of trade was calculated. The time span analyzed starts before the First Oil Crisis (1973) and shortly after the Second Oil Crisis (1982). The turbulences of the world trade system at the time may have caused changing trade patterns, even without changing environmental policies.

Using a similar methodology as Robison, Sorsa (1994) shows that world market shares of a group of countries with high industrial standards in environmentally sensitive goods have not changed much over the last two decades. With the exception of a changing composition of trade with Eastern Europe, Scherp and Suardi (1997) find also that the relative pollution intensity of EU trade has not changed and may have even increased since the 1970s.

This result contrasts with the study by Tobey (1990). He identifies "dirty" industries according to the percentage of abatement expenditures per sector. From this criterion he derives the pollution content of a country's exports, which is regressed on its resource endowments. The inclusion of a dummy variable that measures environmental stringency of the country does not yield any statistically significant impact of environmental regulation on trade patterns.

Van Beers and van den Bergh (1996) develop the approach used by Tobey further and derive a more differentiated result. A broad indicator of environmental policy in the exporting country is significant, but has a positive sign. This positive sign means, environmental policy increases the country's export. However, a narrower indicator of environmental policy developed by the authors shows a significant but negative sign on aggregate trade flows. Most importantl

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importantly, they find a significant negative relationship for highly pollution intensive sectors that are footloose.

Simulation models (Walter 1973, D'Arge 1974; OECD 1978; Pearson 1987; Perroni and Wigle 1995) predict small but discernible effects of pollution control measures on the balance of trade. Tackling the problem in a simulation model, Low (1992) analyzes the consequences of a tax that equates pollution abatement and control expenditures of Mexico with those of the U.S. He reports that his simulations show only negligible effects on Mexican exports. Since Low remains vague about the structural details of the simulation itself, it is difficult to judge its merits.

Location-of-industry studies also provide some insights. The literature is related to studies measuring the locational impact of taxes. Newman and Sullivan (1988) provide a literature review on this type of study. The existing consensus is that differences in taxes are of importance in the intraregional location of firms, while its influence on location decisions between regions is insignificant. Newman and Sullivan, however, consider the latter point to be far from settled. There are formidable econometric problems involved in estimating the tax impacts. Mainly, these problems involve the fact that the *ceteris paribus* condition does not hold. Businesses in general do not mind high taxes, if the local government uses the revenue to provide for services such as a good infrastructure and a good local education level. Taxes that are used for redistributional purposes will be regarded unfavorably.

In general, the *ceteris paribus* variables will be decisive in determining the location of a firm, and this conclusion makes it difficult to isolate the independent influence of taxes. This difficulty is even more pronounced in the case of environmental regulations, which are usually portrayed of having a small role compared to other factors (cp. Motta and Thisse 1993).

On the receiving end, Birdsall and Wheeler (1992) state an increase in international investment in pollution-intensive industries in Latin America because of stricter OECD rules. Molina (1993) suggests a clear relationship between abatement costs and the growth of Mexico's maquiladora industry. Instead of following other studies in regressing abatement costs on the distribution of industries, he regresses abatement on the growth of different industry sectors in the Rio Grande area. Molina finds that those sectors with the highest share of abatement costs were the fastest to expand their activities in the Mexican maquila industry. Indirectly, this may imply a certain degree of industrial flight from the US or elsewhere, although a correlation need not imply causality.

Xing and Kolstad (1997) also arrived at the conclusion that more lax environmental regulations in a host country were significantly correlated with US chemical industry investments. For other industry this link could not be shown. However, they find hints that relaxed environmental regulations in the host country are correlated with higher overall investments by US firms.

Bouman (1996) finds for Germany that compliance costs are slightly related to capital outflows. However, these results are highly dependent on model specifications.

McConnell and Schwab (1990) indicate that differences in environmental regulations among counties in the United States do not appear to influence investment decisions significantly. The empirical evidence for the impact of pollution restrictions on location corresponds to that of short-run tax incentives, a result that is not surprising in light of the similar nature of environmental regulations and taxes as business incentives[8]. On an international level, locational decisions are mostly driven by agglomeration economies, such as infrastructure and other existing industries, with some level of importance attached to classical parameters like market size and labor costs (Wheeler and Mody 1992).

No study seems to state conclusively whether there is a positive, negative, or zero correlation between capital flows and pollution abatement costs. This conclusion is due to the low number of observations used in most studies, as well as a variety of estimation problems. For the high-polluting sectors such as mineral processing, chemicals, pulp and paper, and petroleum, pollution control equipment can cost between roughly 10 and 24 % of new plant equipment in OECD countries (Lucas *et alii* 1992). For these industries, a relocation response to lower environmental standards would not be surprising. This, however, would only concern new factories, not existing ones. Pollution abatement operating costs as a percentage of output value lies in the United States at 0.54 % on average, with the highest value at 3.17 % (Low 1992, 113-4). The low level of these numbers do not point to a mass exodus of United States industry due to differences in environmental regulation.

It has been pointed out, however, by Chapman (1991) that regulation costs are highly underestimated, because the figures do not include items such as workplace health and safety protection costs. A possible counterargument is that these costs could equally be seen as hidden labor costs. This seemingly academic statement points to the problem that if dirty

[8] There is an emerging consensus in the literature that taxes are a more important issue in intrametropolitan location decisions than in intermetropolitan decisions (McConnell and Schwab 1990).

industries are also labor intensive ones, it will be difficult to separate that reason for the relocation of an industry. A statistical regression thus encounters the problem of multicollinearity, in addition to the unavoidable distortions of pressing the complex decisionmaking process for a firm's location into a simple mathematical model.

The argument by Chapman, however, finds support in the study of Gray and Shadbegian (1993). Using a plant-level data set, they find that, statistically, a one-dollar increase in regulation costs is associated with a 3-to-4-dollar drop in productivity. Using these results, the authors find that environmental compliance costs have reduced the average total factor productivity in the paper, oil, and steel industries by 5.3, 3.1, and 7.6 %, respectively. These results appear to be at a higher level of plausibility than those quoted by Low, although they surely will not be the last words written on the subject.

Stafford (1985) uses an approach that circumvents the problem of potentially unreliable pollution cost figures by using personal interviews and questionnaires to identify the factors that were most important for large U.S. corporations in locating their branch plants. The result of the study is that differences in environmental regulations have some influence on location decisions, but rank behind other factors, like labor characteristics, markets, transportation, materials, infrastructure, quality of life, business climate, community characteristics, and taxes. Even for plant types that are qualified as "less clean", the influence of environmental regulations is outweighed by markets, labor, and materials. The influence of regulations seems to be of slightly more importance for the choice of the exact plant site on a local level than on a regional level. The influence of environmental regulations therefore mirrors the influence of taxes on industrial regulation. Stafford's results converge with those of other econometric studies.

However, Stafford's study may underestimate the relocation problem, because the firms in the sample are all members of the Fortune 500. Large enterprises that run a large number of factories will usually avoid the bad publicity of running a hazardous plant. The operation of a plant like Union Carbide's Bhopal generally does not make good business sense for the mother company. Large companies therefore have a tendency to use uniform standards at all production facilities. (Pearson 1987; Warhurst and Isnor 1996, Levy 1995, Leonard 1988). Multinational enterprises generally seek consistent environmental enforcement rather than lax enforcement.

Jaffe *et al.* (1995) summarize intra-US locations studies. The studies summarized find either no significant or very small effects in particular circumstances. There are even hints that low environmental standards can even discourage investment.

A statistical problem that might lead to an understatement of the problem is that it compares only locations within the United States with only a limited variation in environmental relations. There is some reason to believe that the firms for which lax pollution standards are an overwhelming factor are not part of the sample because they invest abroad. In the framework of the industrial flight hypothesis, this approach means that firms are only surveyed if they did not leave the country. Leonard's (1988) study must thus be seen as complementary to that of Stafford, as he analyzes case studies of U.S. firms that left the country. He also finds that, while lax environmental regulations may help to gain a locational advantage, they are usually overwhelmed by other factors.

Stafford provides two important insights by disaggregating the general locational influence of environmental regulation of the firm's decision into its component. The first is that it is not the allowable level of pollution emissions that deters companies, but the level of uncertainty and delay that is involved with the bureaucratic process of obtaining an operating license. The number of required permits are more important than the capital costs of pollution control. This is related to the second insight that firms see environmental regulations as part of a regulatory package. In other words, a helpful bureaucracy that is perceived as pro business will not loose business through strict regulations, as long as it has a clear and quick permit-granting process.

This harmonizes also with the finding of Duerksen and Leonard (1980) that most of the relocation taking place due to regulatory differences flows into other industrialized countries, and not into less-developed countries. Obviously, low emissions standards alone do not suffice in gaining capital inflows.

It has been correctly pointed out by Pearson (1987) that it is not *a priori* clear to believe that the increased output of an environmentally abundant country will be captured by multinationals as opposed to domestic firms. An analysis of the locational patterns of international firms may therefore be the wrong place to look for a solution of the industrial relocation issue. The question of regulation-induced industrial relocation is therefore not yet settled, although there is an indication that it plays some role for especially polluting sectors, as Molina (1993) and Birdsall and Wheeler (1992) suggest.

In summary, it appears that, for the economy as a whole, the fears of industrial flight are largely exaggerated. Comparative advantage in environmental regulations appears to play a role for the location of only a limited set of industries, and is a minor factor for industry in general. Heckscher-Ohlin type trade models (at least in their naive form) are found wanting in predicting the effects of regulations on trade patterns. While of concern for trade theorists, these empirical findings are reassuring for ecologically minded governments. Due to the minor influence of regulations on industrial location, it appears that trade and environmental goals can be pursued largely independently.

1.4.4. Pollution Haven Hypothesis

Related to the industrial flight hypothesis is the pollution haven hypothesis. It states that in an open economy governments are willing to lower envrionmental standards to give a trade advantage to domestic sectors.

In merging the findings of the environmental literature with trade theories, several papers are careful to point out that, in an open economy, an optimal environmental tax is not simply a matter of applying the Pigou theorem (i.e. imposing a marginal emissions charge equal to the marginal externality).[9] The seminal paper was written by Markusen (1975), which addresses the problem in a two-country, two-commodity general equilibrium framework with no substitution possibilities for the production of the polluting good. A Pigouvian tax should be equal to domestic external costs, while the optimal tariff combines the standard optimal tariff with an additional charge that reflects the externality that results from the pollution imported from foreign production. Clearly in this case, the transboundary pollution increases the optimal tariff beyond the level that would prevail in its absence. The Pigouvian tax, however, remains too low to produce a global social optimum.

Krutilla (1991) shows that there are at least two other factors that are to be included in the determination of an optimal pollution tax, even without transboundary flows of pollutants.

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[9] Optimal refers here to the optimal policy of the imposing country only, not what would be optimal under a global welfare function.

The first is the effect of an environmental tax on the terms of trade of a country that was already mentioned in the discussion of Baumol and Oates; the other is the effect on tariff revenue. Both have opposing signs and depend on the position of a country as net exporter or importer of the taxed good, as well as the question of whether the associated externality occurs during its production or consumption.

Taxing a production externality in a country produces benefits by reducing the externality. If the country is a net exporter of the polluting good, it also benefits from improving the terms of trade, thus the tax generates a monopolistic surplus gain on the reduced export volume. An optimal tax thus needs to include the terms-of-trade effects, and is higher than the Pigouvian tax for the net exporter. This result is a standard conclusion of trade and environment modeling (see for example Markusen 1975; Rauscher,1993). The terms of trade effect is large, if the country's supply elasticity is high and the export elasticity is low. If the country is a net importer of the polluting good, the terms of trade effect works to lower the optimal tax below the Pigouvian level, as the country now suffers a terms-of-trade loss through increased and more expensive imports.

There is a second effect, however, which works in the opposite direction of the terms-of-trade effect. In the case of a net exporter, a pollution tax reduces the volume of trade and with it the country's tariff revenues shrink. This effect increases with the tariff rate and does not exist, if the level of tariffs is zero. Krutilla thus hints at the importance of fiscal variables for the analysis of trade and environment interactions. It should be pointed out here that the analysis remains partial and thus incomplete, in that it ignores how the tariff revenues are spent. (As tariff revenues will shrink and pollution taxes increase, the overall direction of the public budget is undetermined.) The argument for a general equilibrium analysis will be explored later.

The analysis of Krutilla has been carried further by Kennedy (1993). Kennedy differs from Krutilla in three crucial points. First and most importantly, Kennedy models strategic interactions between two large trading countries in a game-theoretic framework. This approach means that the analysis moves away from the somewhat unrealistic assumption that the other country does not react to the policy measures in the home country. Whether the assumption of a given--and known--reaction curve by Kennedy is more realistic is another matter. However, it points out the great importance of strategic interactions between countries.

The analysis deviates from Krutilla further in that it assumes imperfect competition, while Krutilla assumes a perfect-competition economy with the import or export status of a country exogenously given. Thirdly, the inclusion of transboundary pollution accentuates the interaction between the two countries in a strategic sense, since the stakes for each country are higher. The analysis is a modification of the optimal tariff literature. Three effects drive the decision concerning the optimal tax on pollution away from the Pigouvian solution. First, there is the rent-capture effect. This effect denotes the change in the surplus generated from foreigners, and includes changes in profits from exports as well as changes in tax revenues from exports. In Kennedy's model, this effect is negative, since increased taxes reduce the level of exports.

Most interestingly, while this effect drives the tax level up in Krutilla's analysis, Kennedy finds it to reduce the optimal tax level. He attributes it to the fact that, in Krutilla's model, trade flows are determined exogenously by traditional forces such as comparative advantage. Facing competitive buyers, the net exporting country is free to use a tax as a means to extract a monopoly rent from the buyers. In Kennedy's framework, the direction of trade is determined exclusively by relative tax rates. The country (that is otherwise equal) which has the lower tax rate will therefore be an exporter, while the other will be an importer. The implications of these modeling differences are quite fundamental, since Krutilla suggests that free trade will not provide an incentive to lower pollution standards, while Kennedy provides ammunition for the side that argues against free trade on the basis that it would erode environmental standards.

Certainly, there are examples of industries that support the arguments on either side. In the cases of an asymmetrical trade integration between poor and rich countries, Kennedy's assumption that both countries have identical endowments is not tenable. There may thus be room for the extraction of monopoly profits from one country, at least in certain industries. On the other hand, with some likelihood, there are industries where the competitive situation in the different countries is quite similar. Differences in environmental regulations may therefore tilt the balance in favor of one or the other country, thus lending plausibility to Kennedy's analysis. Clearly, some analysis or educated guesswork of the competitive structure of key industrial sectors is necessary to determine the net benefits of environmental policies in a free-trade arrangement. In practice, the respective political strength of the potential winners and losers will be decisive in determining the direction in which the rent capture effect will point the environmental regulations.

Two more shifters of environmental policy are identified by Kennedy. The transboundary effect keeps the optimal tax rate below Pigouvian levels, because a country's policy does not account for the pollution that causes damage in other countries. This effect occurs with or without trade. The last effect listed is the familiar pollute-thy-neighbor-via-trade effect, which works to make the pollution policy more stringent than warranted by Pigouvian policy (Siebert 1985).

Using a dual general equilibrium approach to produce results comparable to that of Kennedy, Ulph (1990) finds that quantity instrument are Pareto superior over the tax instrument. The conclusion by Ulph is biased, however, through the fact that it is a partial analysis that neglects that the money earned with the tax instrument may be put into a use other than paying for an unproductive state apparatus, and thus needs to enter welfare considerations.

Further models include dynamic interactions between countries. These models try to overcome the assumption in a comparative static analysis that trade flows are determined solely on the base of factor endowments. Implicit in the traditional trade theory is therefore the assumption that, once a comparative advantage in endowments disappears, trade flows will revert. If this assumption were true, it would be foolish for a government to subsidize the location of a certain industry, because firms would only stay as long as the subsidy is granted. In the economic system of the Heckscher-Ohlin paradigm, history does not matter. Once the initial parameters are replicated, exactly the same structure will be reproduced.

Economic growth is, however, path dependent. Through changes in price levels and the structure of competition, trade can lead to the formation of economies of size and technological innovation. Many government planners therefore believe that locational advantages are self-perpetuating. Effects, such as learning-by-doing and agglomeration economies (i.e., the costs and benefits of geographical concentration) may change the economic structure of a country permanently. Much of the difference between classical trade theory and recent theoretical developments lies in the acknowledgement of the importance of the development path.

Porter (1991; Porter and van der Linde 1995) has turned the argument around and formulated the hypothesis that countries can use the early introduction of environmental policies strategically to give domestic environmental industries a head start compared to foreign competitors. The idea behind the Porter hypothesis is that in countries that regulate early and well (!), companies can move down the learning curve without large market losses to non-regulated competitors. However, by the time competitors start to regulate they will have developed a strong competitive edge. There are many caveats linked to the hypothesis. Most notably, it fails to provide any *ex ante* information on what regulations will be beneficial. For a criticism of the Porter Hypothesis, see Palmer et al. (1995). Their critique relies basically on the fact that firms could spot future business opportunities in the environmental field even without the government.

There are numerous extensions to the game theoretic literature that analyze the problem of organizing the world's countries to cope with transboundary pollution, especially global warming. However, the problem of global commons exceeds the scope of this paper, which focuses on domestic pollution only.

While dynamic and game-theoretic effects are of importance, they are intrinsically difficult to model, and have yielded limited insights in the sense of falsifiable predictions about what governments actually do. Especially, game-theoretic models tend to be intellectually stimulating mind games with no attempt at corroborating their insights with empirical observations. What there is in empirical literature shows little evidence that governments consciously use environmental regulations as instruments of trade-related policy goals in the form of "ecological dumping", an insight which probably is not unrelated to the limited effect such a policy seems to have on the location of industries.

Rauscher (1993) cautions that ecological dumping is not simply identical to having lower environmental standards than other countries. As has been pointed out, there is no reason why environmental regulations should be equal in all countries, since preferences and national endowments vary among regions. The normative statement that regulations should be identical around the world is to be rejected on these grounds. Differences in environmental regulations (at least for local pollution) may be even desirable, as it leads to global welfare increases due to the principles of comparative advantage. Ecological dumping is also not identical with pricing of pollution below marginal social damage. While this pricing certainly produces economic distortions it is not necessarily due to a conscious decision to change trade patterns, but can have many other motivations.

On a practical level, Rauscher proposes a third definition, which states that ecological dumping occurs whenever the (explicit or implicit) price of environmental resources is lower in the tradeables than in the non-tradeables sector. Under this definition, the level of information needed to test for the existence of environmental policies as a means to gain a trade advantage is considerably less than that for the previous definition. It is not necessary to undertake the near-impossible task of analyzing a correct resource price. Instead, one can simply focus on price and regulatory differences. Further, Rauscher's third definition seems to be the most realistic way policymakers would try to take strategic advantage of low regulation levels in a trade setting.

To my knowledge, there exists no study that analyzes methodically, the question of whether states systematically follow a policy of ecological dumping in the sense of Rauscher, although anecdotal evidence exists. The most prominent example of this kind is the exploitation of tropical forests for export. In many cases, however, the policy is not part of a deliberate long-term plan, but emerges from short-term necessity. Of special importance here, is the need to serve huge amounts of foreign debts that might lead Third World countries often to underprice their natural resources (Tudini 1993). Another important area where deliberate discrimination applies is in the field of energy/CO_2 taxation. Since energy can constitute a considerable cost component for certain industries, this is a field where effective tax rates can differ substantially. For the global commons such a tax differentiation may even be beneficial as it reduces carbon leakage (Scherp and Suardi 1997).

It should be noted here that, for the case of medium-income countries the supposition of a pollution-haven strategy may not be the only relevant of the two hypotheses for strategic environmental policy, as they may be squeezed on both sides. Higher environmental standards may decrease the country's attractiveness for capital from rich countries, while its own industry moves towards countries with even lower regulations. An answer to the question of whether trade liberalization improves or deteriorates the environment in medium-income countries, leaves open the question what takes place in other countries. A pollution reduction within the free-trade area could mean that the polluting sectors move to third countries that are more willing to sell off their environment. On a global level, pollution may therefore still rise. There exists, however, to my knowledge no theoretical literature dealing with the trade and environment complex in a three-country framework.

1.4.5. Empirical Evidence of the Pollution Haven Hypothesis

In light of the negligible effect of environmental regulations on trade flows it not surprising that there is no evidence that countries systematically use environmental policy as a means of attracting business. Leonard (1988) screens numerous case studies of industrial relocations of U.S. firms into four industrializing countries for evidence of conscious ecological dumping. While the underpricing of environmental costs seems evident for the case of Romania under Ceausescu, in other countries the evidence points largely to the contrary. After attempts in the 1950s to use lax environmental regulations as a means of attracting foreign investors, Ireland reversed this policy, not least because it had only a small effect on investors. For Mexico and Spain, Leonard finds the contrary policy that environmental regulations are mostly higher on foreign companies than domestic ones. Historically, comparatively low environmental standards are often more the result of ignorance than of conscious decision making. Leonard provides evidence that the medium-income countries become increasingly more adept at obtaining environmental concession from foreign firms, as the countries move down a learning curve.

Murell and Ryterman (1991) analyze whether a comparative advantage in pollution-intensive products could serve as a justification for lax environmental standards. In particular, they conclude that the relatively lax environmental policy in Eastern Europe cannot be explained by a tendency to export commodities intensive in pollution.

1.5. Poverty Attraction Hypothesis

The empirical evidence compiled above indicates that the two components of the traditional pessimism hypothesis have only a very limited backing in the empirical literature. However, this does not eliminate the possibility that trade among countries with unequal level of development results in increased pollution levels.

1.5.1. Conditions for the Hypothesis

While regulation-setting itself may not be important for industrial location, there is a strong possibility that regulations are correlated to other important location factors. Therefore, trade could lead to higher overall emissions, if countries with low environmental standards specialize in pollution intensive sectors, even if the relaxed regulations themselves play a minor role. Since low environmental standards can be found in developing countries and strict standards in industrialized countries, the nature of North-South trade becomes crucial.

This possibility leads directly to the formulation, of what could be labeled the "poverty attraction hypothesis": pollution-intensive sectors tend to be attracted to poor countries. Free trade leads to environmental degradation in poor countries, because the relocation is met with lax environmental regulation. This concern has been formulated early by Walter and Ugelow (1979; see also Copeland and Taylor 1994 1995).

Specialization need not be driven by environmental standards but result from exacerbating factors such labor and capital endowments. The theoretical trade literature is of little help in determining the expected specialization. Depending on the correlation of pollution-intensity with other factors such as labor intensity and capital intensity, North-South specialization could occur in either way. Development theory offers some assistance. It is well established that as countries move through stages of development, their economies become less resource and labor based, and become increasingly capital intensive. However, again it remains an empirical question whether the dominant sectors of early development stages are intrinsically dirty or are polluting because of the coincidentally low pollution standards. Furthermore, it is an empirical question whether trade makes the situation worse.

1.5.2. Empirical Findings on Poverty Attraction Hypothesis

Empirical literature exists on both the trade aspect and the development aspect of the poverty attraction argument. The analysis of trade flows indicates that environmentalist fears of trade specialization are not completely unfounded. A number of empirical studies confirm that developing countries tend to specialize in dirty industries. Low and Yeats (1992) investigate the connection between the pollution content of trade and income level. They find that exports of dirty products account for a growing share of developing countries' exports. Other econometric studies derive at similar results (Hettige et al. 1992; Birdsall and Wheeler 1992). Dessus and Bussolo (1995) achieve this conclusion using a computable general equilibrium model for Costa Rica.

By contrast, Sorsa (1994) shows that industrialized and developing countries roughly maintained their comparative advantage in environmentally sensitive goods. Similarly, Scherp and Suardi (1997) also find that EU-Third World trade specialization was mostly unchanged over 20 years.

The assembled evidence is weakened by the fact that all studies rely on the same emissions data set compiled by the World Bank (Hettige et al. 1995) on which also this study draws. However, the overall balance of the empirical trade literature appears to indicate that developing countries have a comparative advantage in pollution-intensive sectors. Potentially, this conclusion could imply that it is not commendable for a Third World country to follow an open trade policy, because the removal of trade barriers will lead to a worsening of a poor country's environmental and, in the longer run, economic situation.

The empirical literature of the connection between pollution and development hints that the relationship between a country's wealth and pollution follows an inverted U (Selden and Song 1994, 1995; World Bank 1992; Shafik 1994; Grossman and Krueger 1995; de Bruyn et al. 1995, Lucas et al. 1992; Rock 1996; Xapappadeas and Amri 1998)[10]. This phenomenon is known also as environmental Kuznets curve. It denotes the observation that the least developed countries have relatively low levels of toxic release, countries undergoing industrialization are highly polluted, and post-industrial countries are relatively clean.

Grossman and Krueger estimate that the highest level of pollution occurs for countries with a per capita income near US$ 5,000 (at purchasing power parity) which is about the income level of Mexico. Beyond this threshold, increased GDP is correlated with a decrease in pollution, at least in the cross-country data set. Radetzki (1992) notes additionally that the curve is moving down over time. A country today is cleaner than a country in a comparable economic stage of development thirty years ago. The shape and time trend of the curve is also found by Goldemberg (1992) for the consumption of energy per unit of GDP which is ultimately the source of most pollutants. However, these findings are not uncontested: Apart from difficulties of comparing pollution levels across countries, it is neither clear where the turning point might be located, nor does the absolute level of pollution decline in all cases (Esty and Gentry 1998).

The observation of the inverted U curve does not allow to draw any direct inference on the interaction between trade and environment, because it does not measure the composition of the economy as a dependent variable. Rather, it looks directly at emissions which are obviously also influenced by regulation levels. Furthermore, there is no hint at whether trade has any impact on this pattern. Therefore, the findings provide little direct evidence for or against the

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[10] Lopez (1994) derives the result from a theoretical model.

poverty attraction hypothesis. However, it points to the critical nature of assuming constant factor endowments and regulations.

1.6. Research Gaps and Purpose of this Paper

The existing body of literature leaves three important lacunae that will be partly filled by this dissertation. First, this paper will add to the empirical literature on trade and environment interactions. Second, it is one of only very few studies that explicitly include the environmental externality in the analysis. Third, it treats integrates the political process of regulations in the analysis.

1.6.1. Contribution to Empirical Research

The literature on trade and environment has made substantial advances. With the notable exception of the Porter hypothesis, most theoretical papers argue that tighter regulations lead to a comparative disadvantage of the regulated sectors. The important question is rather how important actually is the influence of regulations. The emerging consensus of the empirical literature provides good and bad news. On the one hand, industrial flight of relatively little importance. On the other hand, there are some hints that poor countries have a relative advantage in polluting industries. This paper will take a fresh look at the two hypothesis in the context of NAFTA. In contrast to econometrical approaches that focus naturally on statistical significance, the computable general equilibrium (CGE) approach allows a calculation of absolute levels of importance.

1.6.2. Inclusion of Environmental Externality

The empirical literature focuses on the impact of pollution abatement on trade specialization. Remarkably, it neglects the externality aspect of pollution. Potentially, the integration of externalities into the analysis can significantly effect results. Resource depletion deprives a country of the opportunity to develop other industries such as tourism, which are potentially big foreign-exchange earners. Pollution may harm people and materials or deter industries from locating in a country.

There exists only a small body of descriptive literature that emphasizes the negative aspects of trade liberalization itself. This omission stems from the theory of the second best that the removal of trade distortions can lead to a worsening of a country's situation--environmentally or economically--if other distortions still exist. In an autarkic state it may not be consequential that a natural resource like tropical wood is underpriced. An opening of the borders for exports worsens the effect of the distortion and leads to environmental deterioration.[11] While the argument itself is straightforward, its analytical and empirical examination is made difficult by the complexity of the technical and economic relationships and the often considerable time that elapses between the emission and the time that the full damage occurs. Even if the country gains an advantage in the short-term, a policy-induced comparative advantage in resource-intensive sectors disappears as the resource depletes. An analytical

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[11] There are many examples of this sort. See for example Arden-Clarke (1992a). Some ecological economists take the thought even further and argue that trade generally should be minimized (Morris 1990; Daly 1993; Daly and Cobb 1989). The environmental argument these authors make--there are other ethical considerations not relevant for this paper--is that trade always entails transportation and consequently energy consumption, with all its unwanted side effects of resource depletion, pollution, etc. More trade therefore leads to environmental deterioration. Cross-hauling of near identical goods across borders can be readily accepted as an example of this point. Brander and Krugman (1983) formulate a model where the waste of resources involved in the reciprocal shipping of identical goods may outweigh the benefit of increased competition. It is, however, questionable, whether this should be taken as an argument against trade itself. The real problem lies obviously in the underpricing of the environmental resources. If the "correct" price for energy is so high that trade would fall as a consequence of higher transportation costs, there is still little economic argument for the imposition of trade barriers after the price change.

integration of externality may reveal that lax environmental regulations lead to a deterioration of a country's trade position, as a country's non-polluting export sector declines under the burden of the other sector's pollution.

The static CGE model of this paper addresses the problem by integrating the impact of pollution on health into the analysis. This integration allows an analysis of the welfare impact of policy changes when economic growth and pollution move in opposite direction. Furthermore, it enables to assess the importance of the externality on the industrial structure.

1.6.3. Endogenous Treatment of Pollution Factors

Both theoretical and empirical studies on trade and environment assume factor endowments and institutions to be constant. In combination with the poverty attraction hypothesis, these assumptions result in an easy determinacy of the direction of trade-induced change: Trade is bad for environment because it moves dirty industries to places where regulatory enforcement is weak (even though the enforcement itself may not be the driver). However, it is well established that regulation stringency increases with economic development. The *ceteris paribus* assumption for regulatory stringency is therefore not legitimate, insofar as trade promotes development.

In many cases, the pollution result of the poverty attraction hypothesis reverts, if regulation-setting is treated analytically as an endogenous process. As a complement, this paper therefore formulates a "institutional optimism hypothesis": the relocation of industries cannot be separated from the creation of wealth, which again is a key determinant of a country's regulatory stringency. Since free trade is therefore closely associated with the application of pollution standards, it will generally lead to environmental improvements, even if a country is attractive for pollution-intensive sectors. The institutional optimism hypothesis will be developed formally in Chapter 2. This hypothesis will also be empirically analyzed in the CGE model.

CHAPTER 2

THE INSTITUTIONAL OPTIMISM HYPOTHESIS

The main body of empirical and theoretical literature takes the environmental regulation level as externally given. The present chapter will show the importance of this assumption and argue that it systematically leads to a misjudgment of the environmental consequences of trade liberalization. A first section first develop the economic and political mechanisms justifying an endogenous treatment of regulation levels in the analysis. Section two develops the ideas in a theoretical Heckscher-Ohlin type model that traces the consequences of such an endogenous treatment. A third section interprets the results and formulates the institutional optimism hypothesis. A fourth section will describe a disaggregation procedure for an empirical examination of the hypothesis.

2.1. Economic Development as Explanation of Environmental Stringency

2.1.1. Development and Production Patterns

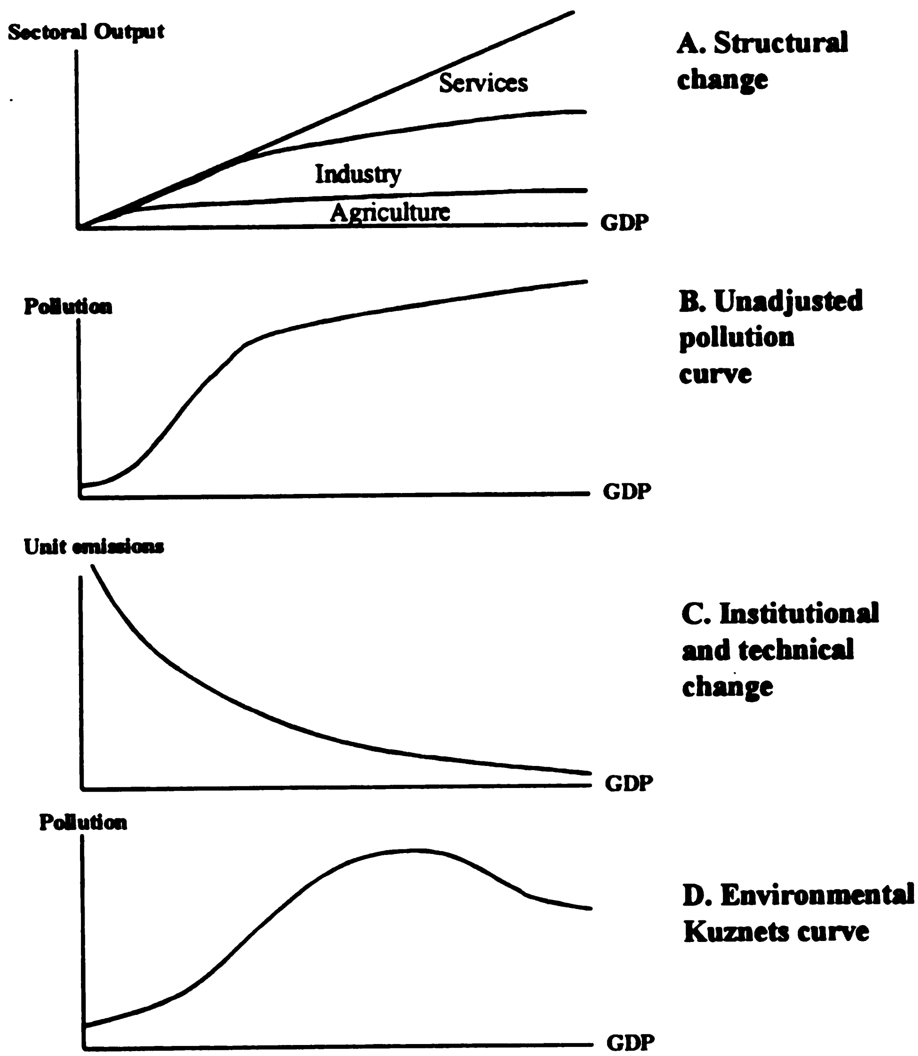
Trade contributes to the economic development of a country. The empirical evidence of an environmental Kuznets curve points to the fact that economic development and pollution do not form a linear relationship. The decomposition of environmental effects serves to disentangle what might explain the relationship. The scale effect in isolation would have suggested that economic development entails a straightforward increase in emission levels. Evidently, therefore during the different stages of economic growth, there must be a distinct pattern that influences the two other important effects identified by Grossman and Krueger (1992), the composition effect and the technology effect. These will be addressed in turn. The stylized facts of the economic development process are presented graphically in Figure 2-1.

Composition effect

Poor and medium income countries tend to have a high share of dirty sectors. (Figure 2-1, panel A). The argument presented here focuses on four factors that explain why poor countries might be prone to having dirty industries. First, poor countries tend to have a high demand for basic production which tends to be dirty, both for final consumption goods, as well as for investment. Consumption in wealthier countries tends to be more service oriented. Second, labor endowment in poor country tends to consist of a pool of unskilled labor. This endowment gives the country a comparative advantage in heavy industrial or agricultural production. Third, poor countries are capital poor. It is not clear whether this poverty should move the sectoral composition of the industry towards clean or dirty sector. However, it contributes to pollution-intensive production technology, as will be elaborated below. Fourth, in poor countries resource extraction tends to have a relatively high share in national production.

All these factor give a comparative advantage to pollution-intensive industries in poor countries. If such countries open to trade, this comparative advantage might be reinforced. In essence, this conclusion is a restatement of the poverty attraction hypothesis. As a country gets richer, the relative advantage might change, and the relative pollution intensity would decrease. In itself, the composition effect might therefore explain part of the relative greening of richer countries. However, it could not explain an absolute drop in pollution levels for rich countries, because structural change is normally not accompanied by an absolute decline but a relative decline of certain sectors (Figure 2-1, panel B).

Figure 2-1. Decomposition of the environmental Kuznets curve



Technology effect

Production technology in poor countries is also largely a function of resource endowment, notably the lack of capital. Physical capital is often of an old vintage. Old vintage capital stock is likely to be more polluting than newer equipment. Retrofitting is generally expensive. Increased wealth and, hence, capital stock tends to reduce emissions first, because environmental improvements are linked to the replacement of the capital stock. Second, because low levels of capital endowment make environmental investments expensive in foregone production. Finally, new and environmentally friendly technologies are often capital intensive. This intensity is due especially to the fact that production processes are mostly developed by rich countries for the need of rich countries. With increased capitalization of production, the likelihood increases that the technology has been developed by the first world, and therefore tends to be environmentally cleaner than the existing technology of the developing country. Increased capitalization of production may therefore lead directly to lower pollution per unit of production, although there exist counter-examples.

Greener production technology is certainly the crucial reason why wealthier countries can be cleaner countries. However, it leaves the question why they actually are cleaner. The inverted U-relationship of pollution appears to indicate an increasing importance of the technology effect from a certain income level onwards. (Figure 2-1, last two panels) This result can be explained only by a look at the institutional aspect of regulation setting that will be discussed more extensively.

2.1.2. Development and Institutions

Pollution control requires the existence of functioning regulatory institutions. The existence of these institutions is intimately tied to a country's wealth, because the demand for environmental quality is highly income elastic. (Esty 1994). Clean environment is a normal good. Its effective demand rises with the level of income. For very poor people, the basic concern is to earn a livelihood for themselves and their families. In such a situation, the concern for the environment tends is not expressed in the market and the political processes. As a country gets richer and its population is increasingly able to bear a reduction in their disposable income, the demand for environmental service increases. If the political process permits it, environmental regulations will become more stringent in such a case.

Furthermore, a clear link can be established between the income and education level of the country and the level of public accountability of the administration (Hettige et al 1996, 1997).[12] The difference in institutional capacity between poor and rich countries is often commented on (Chichilnisky 1994; O'Connor 1994). Dasgupta et al. (1995) find empirically that the amount of regulation increases steadily with the growth of per capita incomes.

There are several arguments that support a behavioral assumption of this type. Foremost, increased wealth (approximated by the capital intensity) decreases the willingness to tolerate pollution. The desire for stricter standards may be the direct result of increased income itself, since a clean environment is something of a luxury good , or may be caused indirectly through higher general education that usually correlates with increased wealth. Inasmuch as environmental awareness and preferences are closely related to people's educational levels, higher income will result in stricter pollution standards. This argument will be elaborated further below.

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[12] Selden and Song (1994) provide similar arguments.

A transactions-cost effect complements the income effect. While the income effect is demand driven and relies on a positive income elasticity of a clean environment, the transactions-cost effect results from changes on the production side. Naturally, enterprises have an incentive to cheat on environmental regulations, if there is little likeliness in getting caught. Monitoring is expensive, however, and almost certainly involves economies of scale. If an economy sets aside a certain percentage of its income for regulatory enforcement, its efficiency is bound to rise as the value of production increases. There are considerable difficulties in statistically verifying this transactions-cost hypothesis. However, the capability of a state to raise tax revenues may serve as a proxy for its ability to enforce regulations in general. Clearly, there is a trend for the share, if not the size, of a country's informal economy to fall as its per-capita income rises. This analogy lends some plausibility to the argument that an increased capital/labor ratio could result in a higher regulatory standard, even if the demand for environmental quality is completely income inelastic.

Chichilnisky (1994) stresses the importance of property rights in determining the relative abundance of a country in natural resources in a North-South trade model. Chichilnisky's discussion shows that property rights by themselves can determine a country's resource abundance. As the strength of the property rights is correlated to the income level of a country, the argument made by Chichilnisky can be seen as a variation of the transactions-cost argument made above.

Despite their seemingly similar implications, the income and the transactions-cost argument differ qualitatively. The former assumes that the regulatory policies are optimal for a given income level, while the latter assumes the existence of distortions. If there exists only an income effect, there is no systematic change in the externality costs, because the marginal costs of pollution rise at the same time that pollution levels decline. For the transactions-cost case, an increase in capital endowment reduces the externality, which is the gap between marginal benefits of production and marginal costs of pollution. (Since the model presented here does not include any externality effects, a distinction is not made in the model.)

The relationship between income and regulatory stringency conforms also with the more sophisticated approach used in the political science literature. One can separate the relationship between income and environmental regulations into two components: preference formation and the translation of preferences into actual policies. It is argued here that increased wealth and socioeconomic development is a contributing factor to both a value system that assigns increased importance to the environment, as well as to more democratic political institutions that react to these preferences.

The conditions for the development of democratic structures are among the oldest topics studied by political scientists. Explanatory models stress the importance of cultural or of socioeconomic factors (Arat 1988, p.21). For instance, Inglehard (1990) describes how economic development is accompanied by a complex change in the socioeconomic and political system. He identifies several levels at which political changes take place.

First, a certain level of economic and technological development is a necessary condition for the increased importance of post-materialistic values, because it liberates people from concern about basic economic security. Essentially, this requirement means that people move up the Maslow pyramid of needs as more basic wants are satisfied. Secondly, this movement is reinforced through rising levels of education of the general population. These first two factors were already identified earlier. A third factor influencing values is what Inglehard calls distinctive cohort experiences. The history and culture of a country are important factors, since they shape the thinking of a cohort in their formative years. Socioeconomic change usually has little effect on the values of cohorts whose way of thinking is set, but influences mainly the younger generations. Value change therefore is usually associated with generational change. A changing set of values would, however, be inconsequential if no political skills exist that translate the values into politics. These skills are shaped through experiences and learning-by-doing of the cohort, and are furthered through the expansion of mass media, which enlarge the pool of people who have access to information on the political process.

The combined changes in values and skills induced by economic progress exert pressure that makes environmental issues more relevant, and strengthens the channels of political conflict that will translate this pressure into practical politics, or more concretely into stricter environmental regulation. Further factors omitted by Inglehard, such as income distribution are likely to work in the same direction. There exists empirical evidence to support the argument. For example, Dahl (1971) and Arat (1988) establish a positive relationship between economic variables and political freedom and democracy.

One can establish from the accumulated economic and political evidence a direct link between increased income and stronger institutions to protect the environment. A simplified equation (e.g. as an income elasticity of emission standards) can therefore be directly used in economic modeling. Such an analytical representation will be central to the further argument of this paper. However, a few interpretative caveats apply to such a simplified equation.

Most importantly, the described socio-political changes do not occur with necessity or instantaneously. It would not difficult to find various reasons and cases that would contradict such an short-term interpretation of the relationship.[13] However, an income-elasticity of regulation exists as a long-term trend with an interpretation that is similar to that of a long-term equilibrium of an economy: a useful simplification of the real world. In a comparative static equilibrium analysis it can be simply understood as marking the pressure on the economy that is induced by a certain set of policy changes.

Furthermore, a comparative static analysis leaves out the important questions of the transition process to the new equilibrium. Conceivably, an environmental resource could be irretrievably lost in the transition period. The movement to a different equilibrium might therefore be unattainable because, in the interim, the very conditions for the existence of the other equilibrium are destroyed.

Finally, for purposes of modeling, a smooth function serves as approximation of the process towards stricter regulations. By contrast in real life, political and regulatory change often takes place in a discrete rather than a continuous fashion. However, it is not possible, *ex ante* to know exactly where, if at all, there might be thresholds above which certain changes take place.

2.1.3. Trade and Environmental Regulation

It is clear from the previous discussion that environmental standards cannot simply be taken as given. On the one hand trade might improve environmental performance directly. Trade itself, as opposed to autarky, increases the stock of knowledge by giving a country

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13 One may think of the example of the old Soviet Union as a state for which most socioeconomic indicators would suggest the existence of a high degree of democratization and concern for the environment, but where both are conspicuously absent.

access to foreign innovations and knowledge (Grossman and Helpman 1995). Trade openness itself might therefore be associated with a cleaner industrial base. Lucas *et al.* (1992) derived that open economies show a significantly lesser growth in pollution levels than closed economies. Birdsall and Wheeler's (1992) analysis of the situation in Latin America, shows that openness for trade leads to a lower level of environmental degradation, since trade involves a transfer of technology. Wheeler and Martin (1992) present anecdotal evidence that, in the case of the paper and pulp industry in Latin America, investment by foreign firms appears to be followed by the import of pollution-control technology as well as industrial country pollution standards. Openness of the economy is a major factor for the adoption of pollution-saving technology, because it removes existing distortions. By contrast, the authors find no independent effect of a country's development level on the adoption of clean technology.

However, the evidence on outward orientation and decreasing pollution-intensity has been questioned by Rock (1996). As a more political component of the direct effect of trade on regulation, one might also add the political pressure from trading partners, for instance, in the context of NAFTA.

Potentially as important as the effect of trade liberalization of the poorer country's economic structure may be the deregulation of its financial markets. In the context of NAFTA, some studies assume that it would reduce the risk premium on Mexican capital rates by 1 percentage point (CBO 1992). To this one would need to add the effect of increased efficiency in financial services due to U.S. competition and the inflow of U.S. capital. Mexican investment is likely to increase as a consequence, which by itself may lead to increased or decreased pollution, depending on the type of investment that is induced. In general, however, a lower discount rate shifts the trade-off between resource conservation and depletion in favor of a lower rate of exploitation. The interest rate effect may thus work as a factor that pushes Mexico into becoming a cleaner country.

Another line of argument follows directly from the discussion of the previous section and takes the link between wealth and institutions as a starting point. There is no theoretical or empirical trade literature that treats environmental regulation directly as a function of wealth. However, Chichilnisky (1994) makes environmental stringency endogenous to the analysis through a property-rights determined supply function. She assumes the property-rights situation in the North to be well defined, so that here the supply curve of the natural resource follows the social optimum. In the South, the lack of enforcement leads to a more outward-lying private supply curve, which does not consider externalities. In a general-equilibrium framework, she derives that the supply curve for the natural resource can be downward-sloping.

The model assumes that the private suppliers of the resource have no alternative employment than to bring their labor into the production of the resource, while they consume a second good which they purchase from their revenues. Under these assumptions, their optimal allocation problem is one between consumption of the good and leisure time. When the price of the resource falls, two effects occur. The first is the substitution effect: Work decreases as the reward for working declines. The second is the income effect: As wages fall low enough, more effort needs to be applied to earn the subsistence income. In this case, resource exploitation will increase as the terms of trade turn against the resource.

Raising the capital intensity will increase the factor reward for resource exploitation and may therefore lead to a decreased level of exploitation, if the economy operates on the backward-bending part of the environmental supply curve. Raising a tax on the exploitation of the resource, on the other hand, could produce an unintended rise in environmental destruction, increase the comparative resource abundance of the South, and lead to exports of resource-intensive goods. The property rights determined resource abundance is therefore similar in result as the wealth determined regulation setting.

Bommer and Schulze (1996) provide another attempt to the author to internalize the pollution stringency level into the trade analysis. In many respects their theoretical model which is also applied to the NAFTA situation parallels the ideas that will be developed in this chapter. However, the Bommer-Schulze political paradigm is substantially different from the one that will be developed further below. Following Stigler's (1971) and Peltzman's (1976) theory of regulation, in the Bommer-Schulze model, the administration sets environmental standards to maximize a political support function composed of net exporting sectors, net importing sectors, workers and environmentalists. As trade liberalization changes the relative well-being of these four groups, environmental policies need to counterbalance the negative effects on the losing groups.

Bommer and Schulze establish that United States exports are relatively more pollution-intensive than imports. Taking the United States as a vantagepoint, they argue that trade liberalization with Mexico puts exporters and labor on the winning side, while importers and environmental interests suffer. They then argue that this constellation automatically puts pressure on the administration to increase the stringency of environmental legislation, which serves the interests of the two losing actors. Environmental interests are helped for obvious reasons; importers are helped because they are not pollution intensive and could thus improve their relative position. The authors claim that the environmental side agreements of NAFTA are evidence of this hypothesis.

However, several core assumptions of the Bommer-Schulze hypothesis are inaccurate. Importantly, while it may be correct that the United States exporting industries are relatively pollution-intensive compared to importing industries, this relationship is unlikely to be true for actual embodied pollution, because US regulations are more stringent than those in the rest of the world (see discussion in Chapter 4). The NAFTA-environment discussion in the US was dominated by fear that polluting industry would migrate to Mexico due to their lower environmental standards (the industrial flight hypothesis in our terms). The assumption that trade is perceived by environmentalists as pollution-increasing is certainly correct. However, the line of argument was not that pollution would increase in the US but in Mexico. Bommer and Schulze therefore misjudge the US debate on Mexico as a pollution haven and the possible erosion of US environmental standards as a consequence. As a result, the NAFTA environmental side agreements were not directed at manufacturers in the US as implied by the authors, but at manufacturers in Mexico.

Furthermore, while it may be correct that in the long-run US workers might benefit from a trade agreement, this fact does not translate politically into the direction pointed out by Bommer and Schulze, because Labor perceived itself as a loser, not a winner of NAFTA. Possible reasons for this may be the resulting insecurity of structural change, the fact that (losing) incumbents are better organized than the diffuse and uncertain winners of trade liberalization, or simply the fact that certain segments within labor, like the unskilled, might lose while others, like the university trained, might gain.

Therefore, the internalization approach of our paper follows a different route of internalization, using the income level as the factor in determining stringency in environmental regulation.

2.2 Trade Model with Endogenous Environmental Regulation

This section develops the arguments of the previous section in an analytical model. The mathematically disinclined reader might move on to section 2.3. without loss in the argument.

2.2.1. The Standard Model

Following the standard assumptions of trade modeling, a Heckscher-Ohlin world is assumed with two traded goods *X* and *Y*. The home country is small and takes the price levels as really externally given. The price of good *Y* is used as denominator for all prices. *P* denotes the costs of a unit of *X* in units of *Y*, similarly, *w* and *r* denote the wage rate and the return on capital. We assume that all parameters are within a range that prohibits a complete specialization of the country.

The imported good *Y* is produced following a Cobb-Douglas function that uses capital (*K*) and labor (*L*) as inputs. For the production of the export good *X* an additional environmental input (*E*) is needed, according to a the production function:

2.1 $$X = E_x^{\varepsilon} L_x^{\lambda} K_x^{\kappa}$$

where $\varepsilon, \lambda, \varkappa > 0$, $\varepsilon + \lambda + \varkappa = 1$. This equation means that the production function is linearly homogenous in its inputs which is the standard assumption in Heckscher-Ohlin models. In the absence of a regulation, the producers would use an infinite amount of the environmental input *E*. In order to limit the use of the environmental input, it is now assumed that the government is willing to accept pollution only if it produces a certain level of output. Mathematically, this assumption is expressed as the condition that the marginal productivity of environment has to be at least μ.[14] This first-order condition for the producers of X can then be written as:

$$2.2 \qquad \mu = \varepsilon E^{\varepsilon-1} L_x^{\lambda} K_X^{\varkappa}$$

Solving this for E produces

$$2.3 \qquad X = \left(\frac{\varepsilon}{\mu}\right)^{\frac{1}{\lambda+\varkappa}} L_x^{\frac{\lambda}{\lambda+\varkappa}} K_x^{\frac{\varkappa}{\lambda+\varkappa}}$$

If the factor reward is not taxed away, but stays with the producers of good X, we can substitute equation 2.3 back into the production function (equation 2.1) and obtain:

$$2.4 \qquad X = \left(\frac{\varepsilon}{\mu}\right)^{\frac{\varepsilon}{\lambda+\varkappa}} L_x^{\frac{\lambda}{\lambda+\varkappa}} K_x^{\frac{\varkappa}{\lambda+\varkappa}}$$

It can be easily seen that the production function of X with endogenous E is linearly homogenous in K and L. To avoid notational clutter, let us rewrite the production function as:

$$2.5 \qquad X = \left(\frac{\varepsilon}{\mu}\right)^{\beta} L_x^{\alpha} K_x^{1-\alpha}$$

where $a = \dfrac{\lambda}{\lambda+\varkappa}$ 1 and $\beta = \dfrac{\varepsilon}{\lambda+\varkappa} = \dfrac{\varepsilon}{1-\varepsilon}$. α marks the adjusted new factor share of labor, while β can be interpreted as the relative increase in the return of the non-environmental inputs that can be ascribed to the environment. If ε is 0.25, then the returns to labor and capital are augmented by one third. It can be seen that pollution is a simple linear function of X.

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[14] This approach has been used by McGuire 1982.

2.6 $$E = \frac{\varepsilon}{\mu} X$$

The environmental intensity is related inversely to the minimum marginal productivity, but rises with the factor share ε of the environmental input. The production of Y is assumed to produce no environmental externalities. Its production function is

2.7 $$Y = L_y^{\delta a} K_x^{1-\delta a}$$

The labor intensity of Y is δ times that of good X. A value for δ smaller than 1 means that polluting good is also relatively labor intensive, which would approximate the relative position of the poorer country. From these assumptions, we can derive the first-order conditions

2.8 $$w = pa\left(\frac{\varepsilon}{\mu}\right)^{\beta}\left(\frac{K_x}{L_x}\right)^{1-a} = \delta a\left(\frac{K_y}{L_y}\right)^{1-\delta a}$$

and

2.9 $$r = p(1-a)\left(\frac{\varepsilon}{\mu}\right)^{\beta}\left(\frac{L_x}{K_x}\right)^{a} = (1-\delta a)\left(\frac{L_y}{K_y}\right)^{\delta a}$$

The capital-labor ratio is a function of the wage-profit ratio.

2.10 $$\frac{w}{r} = \frac{a}{1-a}\frac{K_x}{L_x} = \frac{\delta a}{1-\delta a}\frac{K_y}{L_y}$$

This can be transformed into

2.11 $$\frac{K_x}{L_x} = \frac{\delta - \delta a}{1-\delta a}\frac{K_y}{L_y} = \psi\frac{K_y}{L_y}$$

where $\psi = \dfrac{\delta + \delta a}{1 + \delta a}$ marks the difference in the capital/labor ratios. If X is relatively more labor intensive than Y, then $\delta < 1$, and $\psi < 1$. Substitution of equation 2.9 into 2.11 yields equation 2.12.

2.12 $$K_y = \left(\frac{p}{\delta}\right)^{\frac{1}{a(\delta-1)}} \left(\frac{\varepsilon}{\mu}\right)^{\frac{\beta}{a(\delta-1)}} \psi^{\frac{a-1}{a(\delta-1)}} L_y$$

If the total stock of labor and capital is limited by the equations

2.13a $$K = K_x + K_y$$

2.13b $$L = L_x + L_y$$

the model is solvable and the following results are obtained:

2.14a $$L_y = \frac{\psi}{1-\psi}\left[-L + \left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}}\right)^{\frac{1}{a(\delta-1)}} \psi^{\frac{-(1-\delta a)}{a(1-\delta)}} K\right]$$

2.14b $$K_y = \frac{1}{1-\psi}\left[-\left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}}\right)^{\frac{1}{a(1-\delta)}} \psi^{\frac{1-\delta a}{a(1-\delta)}} K\right]$$

2.14c $$L_x = \frac{1}{1-\psi}\left[L - \left(\frac{p\,\varepsilon^{\beta}}{\delta\mu^{\beta}}\right)^{\frac{1}{a(\delta-1)}} \psi^{\frac{-(1-a)}{a(1-\delta)}} K\right]$$

2.14d $$K_x = \frac{\psi}{1-\psi}\left[\left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}}\right)^{\frac{1}{a(1-\delta)}} \psi^{\frac{1-a}{a(1-\delta)}} L - K\right]$$

Further

2.15a $$w = \delta a \left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{1-\delta a}{a(1-\delta)}} \psi^{\frac{(1-\delta a)(1-a)}{a(1-\delta)}}$$

2.15b $$r = (1-\delta a) \left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{\delta}{\delta-1}} \psi^{\frac{\delta(1-a)}{(\delta-1)}}$$

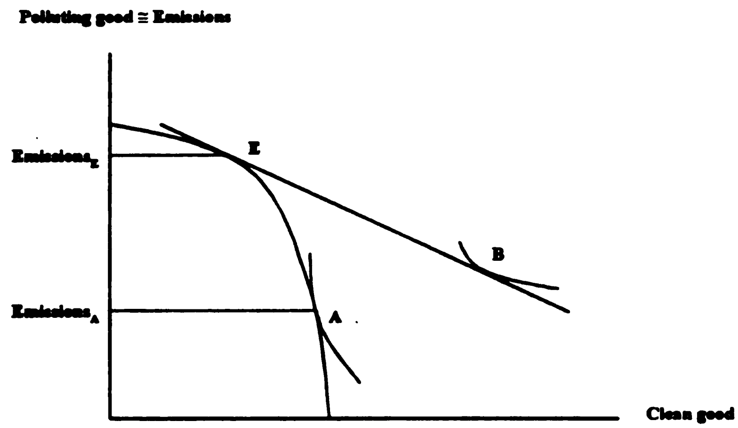
and

2.16a $$Y = \frac{1}{1-\psi} \left[-\left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{1-\delta a}{a(1-\delta)}} \psi^{\frac{1-2a\delta+a^{2}\delta}{a(1-\delta)}} L + \left(\frac{p\,\tau^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{\delta}{\delta-1}} \psi^{\frac{\delta(1-a)}{\delta-1}} K \right]$$

2.16b $$X = \frac{1}{1-\psi} \frac{\delta}{P} \left[\left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{1-a\delta}{a(1-\delta)}} \psi^{\frac{(1-a\delta)(1-a)}{a(1-\delta)}} L - \left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}} \right)^{\frac{-\delta}{1-\delta}} \psi^{\frac{-\delta(1-a)}{1-\delta}} K \right]$$

These equations reproduce the standard Heckscher-Ohlin results. Equation 2.16b for instance reveals that an increase in the capital stock lowers the output of X, if X is relatively labor-intensive, i.e. δ is smaller than 1. This is the Rybczynski theorem. Similarly, it can be verified that the Stolper-Samuelson theorem holds in the model. If the relative price of X increases, the relative wage rate will rise, if labor is the factor that is used intensively in the production of X.

Figure 2-2. Trade liberalization with constant environmental regulations



Since the country is assumed to have a comparative advantage in the production of *X*, trade liberalization would result in an increase in its relative price. A higher *P* results in an increased production of *X* for the export market, while the production of *Y* drops and is partially replaced through imports. In Figure 2-2, production moves from the autarky production point A on the production possibility frontier to point E under open trade. Consumption now takes place at point B. The improved terms of trade for the polluting sector result in an increased production. Because resource use is a simple multiple of the production of *X* as defined by equation 2.5, pollution will increase in parallel.

The model presents the standard arguments of the consequences of trade liberalization. For a country with low pollution standards, trade liberalization leads to an increased production of the pollution intensive good and, consequently, to an environmental deterioration in the home country. Trade liberalization can potentially be welfare reducing, if the increased consumption in the country, which moves from A in Figure 2-2 to B, does not compensate for the increased pollution that the population now suffers. A low emissions standard μ serves as a substitute for a high price level *P* and exacerbates the situation. In graphical terms, lax pollution requirements move the production possibility frontier inward.

2.2.2. The Modified Model

Several mechanisms could make μ, which denotes the trade-off between production and environment that the population is willing to accept, model endogenous. In this paper, we propose a dependence of μ on the capital-labor ratio of X according to the functional form:

$$\mu = \left(\frac{K_x}{L_x}\right)^{\eta} \tag{2.17}$$

This means the required marginal productivity of T increases exponentially with the capital intensity. This is a useful proxy for what would more precisely be represented as an income elasticity of regulation. However, setting η as a function of U would extremely complicate the analysis without adding anything to the argument developed here. With these preliminaries, the model can now be solved. Using the equation

$$\frac{K_x}{L_x} = \left(\frac{p\,\varepsilon^{\beta}}{\delta\,\mu^{\beta}}\right)^{\frac{1}{a(1-\delta)}} \psi^{\frac{1-a\delta}{a(1-\delta)}} \tag{2.18}$$

and substituting equation 2.17) yields the following formula for μ:

$$\mu = \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{\eta}{a(1-\delta)+\eta\beta}} \psi^{\frac{\eta(1-a\delta)}{a(1-\delta)+\eta\beta}} \tag{2.19}$$

If we substitute equation 2.19 into equations 2.14 and 2.16 of the previous chapter, the results change into

2.20a
$$L_y = \frac{\psi}{1-\psi}\left[-L + \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{-1}{a(1-\delta)+\eta\beta}} \psi^{\frac{1-\delta a}{a(1-\delta)+\eta\beta}} K\right]$$

2.20b
$$K_y = \frac{1}{1-\psi}\left[-\left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{1}{a(1-\delta)+\eta\beta}} \psi^{\frac{1-\delta a}{a(1-\delta)+\eta\beta}} L + K\right]$$

2.20c
$$L_x = \frac{1}{1-\psi}\left[L - \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{-1}{a(1-\delta)+\eta\beta}} \psi^{\frac{-(1-a-\eta\beta)}{a(1-\delta)+\eta\beta}} K\right]$$

2.20d
$$K_x = \frac{\psi}{1-\psi}\left[\left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{1}{a(1-\delta)\eta\beta}} \psi^{\frac{1-a-\eta\beta}{a(1-\delta)+\eta\beta}} L - K\right]$$

and

2.21a
$$Y = \frac{1}{1-\psi}\left[-\left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{1-a\delta}{a(1-\delta)+\eta\beta}} \psi^{\frac{1-2a\delta+a^{2}\delta+\eta\beta a\delta}{a(1-\delta)+\eta\beta}} L + \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{-a\delta}{a(1-\delta)+\eta\beta}} \psi^{\frac{-a\delta(1-a-\eta\beta)}{a(1-\delta)+\eta\beta}} K\right]$$

2.21b
$$X = \frac{\varepsilon^{\beta}}{1-\psi}\left[\left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{1-a-\eta\beta}{a(1-\delta)+\eta\beta}} \psi^{\frac{1-a-a\delta(1-\delta)}{a(1-\delta)-\eta\beta}} L - \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{-a-\eta\beta}{a(1-\delta)+\eta\beta}} \psi^{\frac{-a-\eta\beta}{a(1-\delta)+\eta\beta}} K\right]$$

The behavior of pollution is now

2.22
$$E = \frac{\varepsilon^{1+\beta}}{1-\psi}\left[\left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{1-a-\eta(1-\beta)}{a(1-\delta)+\eta\beta}} \psi^{\frac{1-a-\eta+a\delta(1-\delta+\eta)}{a(1-\delta)+\eta\beta}} L - \left(\frac{p\,\varepsilon^{\beta}}{\delta}\right)^{\frac{-a-\eta(1+\beta)}{a(1-\delta)+\eta\beta}} \psi^{\frac{-a-\eta(1+\beta-a\delta)}{a(1-\delta)+\eta\beta}} K\right]$$

If η is equal to 0, no income effect exists and the outcome is identical to the previous results from equations 2.14 and 2.15. However, as η increases, the model results change qualitatively. There exist three value ranges for the pollution elasticity. If η is low, the standard result occurs: An increase in the price of the polluting good increases both the output and the pollution level. If η is at a medium level, X will be strictly increasing, but the pollution level will start to drop beyond a certain level, as the increase in the output of the polluting good is overcompensated through increasingly stricter regulations. At high levels of η, finally, both the production of X and the level of pollution begin to fall beyond a certain level. These results are summarized in Table 2.1.

Figure 2-3: Trade liberalization with endogenous environmental regulation setting

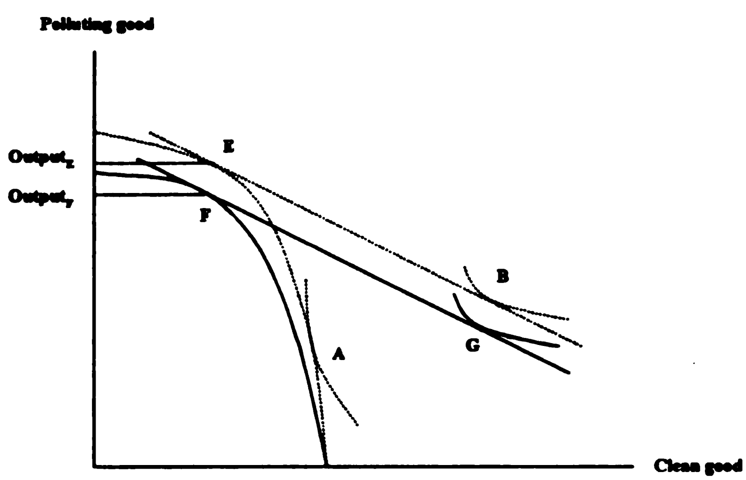


Table 2-1: Summary of Model Results

Range of η	X as function of P	E as function of P
$\eta < \frac{1-a}{1+\beta}$	Increasing	Increasing
$\frac{1-\alpha}{1+\beta} < \eta < \frac{1-\alpha}{\beta}$	Increasing	Inverted U
$\frac{1-\alpha}{\beta} < \eta$	Inverted U	Inverted U

The model demonstrates how the existence of an income effect can fundamentally alter the environmental effect of trade liberalization. Trade liberalization can potentially reduce the pollution even in the country with a comparative advantage in the pollution-intensive good. Figure 2-3 depicts the mechanism graphically: A again denotes the production and consumption level in the state of autarky. It is the tangency point of the indifference curve under the pollution constraint level μ_a, which reflects the price level under autarky (shown as the dotted line). With constant regulations, consumption would move to point B and consumption to point E. However, these points are not compatible with the effect that the price level has on the stringency of the pollution standards. Since μ increases as a result of trade opening, the production frontier moves inward (the solid line). This means that production moves now to point F while consumption takes place at point G. Therefore, an unadjusted calculation of the trade effect will overestimate the increase in the polluting good. Even more so will it overestimate the induced pollution effect.

2.3. The Institutional Optimism Hypothesis

2.3.1. Formulation of the Hypothesis

For a country that has a comparative advantage in pollution-intensive industries, the impact of trade liberalization on pollution is *a priori* ambivalent. One can identify two effects working in opposite directions. First, the country will specialize in the pollution intensive industry, which results both in an increased scale of the economy and in an altered composition. This result is at the heart of the traditional hypothesis and, in a modified form, of the poverty attraction hypothesis. A second often-neglected effect of trade is on the environmental institutions through wealth creation. Section 2.1. discussed the mechanisms through which trade liberalization tends to strengthen the functioning of regulatory institutions.

Section 2.2 presented an analytical model that discusses the interaction of the specialization and regulation effects of trade. Which one of the two dominates, is an empirical question. Its answer is at the heart of the trade and environment debate. It can be formulated as a third big empirical hypothesis on trade and environment, the institutional optimism hypothesis. Since free trade is closely associated with the application of pollution standards (mainly through wealth creation), it will generally lead to environmental improvements, even if a country is attractive for pollution-intensive sectors.

On the empirical answer to the hypothesis ultimately hinges the question whether trade as such is good or bad for the environment. Indirectly, it is also of fundamental importance concerning the strategy environmental interests should pursue vis-à-vis trade issues. In moving this issue forward, the remainder of this section will address the question what empirical evidence might corroborate the institutional optimism hypothesis. Section 2.4. will develop some methodological preliminaries.

2.3.2. Empirical Evidence

There is no empirical evidence that tests the institutional optimism hypothesis directly. A full econometric analysis of the issue would require the statistically difficult separation of is two counteracting effects. Even the separate analysis of the specialization and the institutional effect is lacking. In the context of industrial flight hypothesis, the previous chapter showed that few of the regressions of trade specialization on explanatory variables yielded statistically significant results. On the impact of wealth on regulatory stringency, the discussion above pointed to substantive anecdotal evidence. Difficulties of having a good yardstick for environmental stringency is a major obstacle to a more detailed statistical analysis. Much analysis is therefore based on measuring pollution levels instead of environmental regulation, for instance the literature on the environmental Kuznets curve.

Nevertheless, the environmental Kuznets curve can be taken as indirect evidence for the institutional optimism hypothesis. It is clear on the one hand, that the curve is also compatible with other explanatory models, such as the standard path of economic development and the associated changes in economic composition. In decomposing the pollution-income effect, Lucas et al. (1992) have found supporting evidence for this hypothesis that pollution reduction is due mainly to a composition effect. High pollution may thus be just a function of early industrialization, which relies heavily on mineral processing and other relatively dirty industry, while the income effect on regulations may be of only secondary importance. On the other hand, it cannot be excluded that the changing industrial structure is not to some extent caused by changes in environmental legislation.

However, it is unlikely that the composition effect alone would suffice to generate a downward trend in absolute pollution levels. Principally, only the regulation effect could achieve this alone. However, this effect would need to be fairly high to compensate both for scale and composition effect. If the composition effect were zero, the regulation effect would have to be larger than one. The analytical model in the previous section shows that the introduction of a regulation effect can reproduce the inverted U-shape. However, the analytical result relies not just on the regulation effect, but also on the composition effect (through a lower output of the polluting good) and the scale effect (low overall output).

The difficulty in interpreting the results of the environmental Kuznets curve is that the analysis is results-based. The statistical relationship between income and pollution need not imply a causal relationship. This means it considers the development of environmental indicators without the decomposing whether it is due to changing economic composition, more stringent regulation or technical progress.

A separate problem in this context is that not only might higher income lead to stricter regulation but also environmental regulations determine the potential for economic growth. On the one hand, strict regulations might make an area unattractive for a number of enterprises. On the other hand, a clean environment and low externalities might make the area more attractive for other sectors.

To answer this question, it is necessary to statistically separate the bi-directional causal relationship between income and regulation. This is inherently impossible to do with simple cross-country data sets, but time-series data are necessary. Although he does not analyze exactly the question at hand, the study by Schimmelpfennig (1992) is worth noticing as a first attempt at statistically separating the bi-directional relationship between income and pollution levels. Using time-series county data of the U.S., he finds that an increase in the level of income causes a higher level of pollution, while there is some, though not significant, evidence that lower pollution improves economic productivity. While cross-country studies are often a means of necessity, because there exist few reliable time series on pollution data, they do not necessarily allow the conclusion that the functional relationships established here pertain also in a time path.

2.4. An Illustrative Application of the Institutional Optimism Hypothesis: A decomposition procedure

2.4.1. Introduction and Case Description

The discussion of the previous section shows that the empirical information on the overall pollution level of a country does not suffice to provide strong evidence about the causes of the overall effect. Much less is there any hint as to how trade might influence the result, because of the interplay of scale, composition and regulation effect. More than the industrial flight and the poverty attraction hypothesis, the institutional optimism requires a disaggregation of the overall pollution impact into components. This section will develop such decomposition with an illustrative example. We consider a simple Ricardian case of trade liberalization. The example reflects very closely the mechanisms at work in a CGE model, it also illustrates the taxonomy that will be used in the rest of the text.

Table 2.2 lists outputs, inputs, consumption, and emissions for two countries A and B, where A is more efficient at producing X, while B is better at producing Y. For illustrative purposes we assume a Cobb-Douglas utility function with equal weights for both goods.

Table 2.2: The effect of trade on two fictive economies

Scenario	Region	Output		Consumption		Emissions			Welfare
		X	Y	X	Y	X	Y	Total	
0. Autarky	Country A	20	10	20	10	40	30	70	14.1
(Emission fac-	Country B	10	20	10	20	20	60	80	14.1
tor x=2;y=3)	World	30	30	30	30	60	90	150	Ø14.1
1. Trade	Country A	20	10	15	15	40	30	70	15
without produc-	Country B	10	20	15	15	20	60	80	15
tion changes	World	30	30	30	30	60	90	150	Ø15
2. Trade with	Country A	40	-	20	20	80	-	80	20
production	Country B	-	40	20	20	-	120	120	20
changes	World	40	40	40	40	80	120	200	Ø20
3. Regulations:	Country A	36	-	18	18	54	-	54	18
Emissions -25%	Country B	-	36	18	18	-	81	81	18
Output -10%;	World	36	36	36	36	54	81	135	Ø18

Note: Utility $U = X^{0.5} Y^{0.5}$. This excludes any externalities

In the autarky case both countries consume their output in a ratio of 2 to 1 depending on the relative advantage. They achieve a utility level of 14.1, while pollution lies at 70 and 80 units, respectively. The aspect of trade liberalization can now be disaggregated into three steps.

1. Trade without changes in production: In this case, the only adjustment would take place in the consumption pattern. This increases welfare to a level of 15, but does not use a country's comparative advantage. It has no consequence for pollution. This step shows the barter effect of trade. However, further below, the broader term allocation effect is used, which includes two further components. The first additional component is the gain transaction efficiency implied by reduced rent-seeking when non-tariff barriers are removed. The second component is the scale economy that is made possible by the increased trade. The inclusion of the transaction and scale efficiency also explains why the allocation effect is relatively larger in the model than would be suggested by an inspection based on this simple example.

2. Trade with production changes: In adjusting production, welfare increases in both countries to a level of 20. Pollution, which is linked to the output, rises to 80 or 120. This step shows the structural or specialization effect of trade liberalization.

3. Changing regulation: Here it is assumed that induced by the trade, both countries adopt stricter regulations, lowering emissions by 25 percent and output by 10 percent. The change in output is introduced here for didactic purposes. Insofar as reduced emissions lead to lower externalities, the output level might even increase.

2.4.2. Decomposition with Constant Regulation Level

From the values in the table, the calculations for disaggregating the pollution effect can be made. First, we ignore the step of increased regulations. This yields the summary Table 2.3:

Table 2.3: Pollution effect of trade liberalization with constant abatement

	Country A	Country B
Pollution Effect	+14.3%	+50.0%
Scale effect	+41.0%	+41.0%
Allocation effect	-6.4%	-6.4%
Composition effect	-14.3%	+12.5%

The values for the constant abatement case result from the following calculations:

1. Total pollution effect: A) +14.3%; B) + 50 %; Calculation:

$$\frac{Emissions_2}{Emissions_0} - 1 = A)\frac{80}{70} - 1; B)\frac{120}{80} - 1$$

2. Scale effect: +41%;

Calculation: $\frac{U_2}{U_0} - 1 = \frac{20}{14.1} - 1$

3. Output effect: + 33.3 %; (This is an intermediate step for calculating allocation and composition effect).

Calculation: $\frac{Output_2}{Output_0} - 1 = \frac{40}{30} - 1$

4. Allocation (barter) effect: -6.4%;

Calculation: $1 - \frac{U_1}{U_0} = 1 - \frac{15}{14.1}$

The relationship between the three effects is:

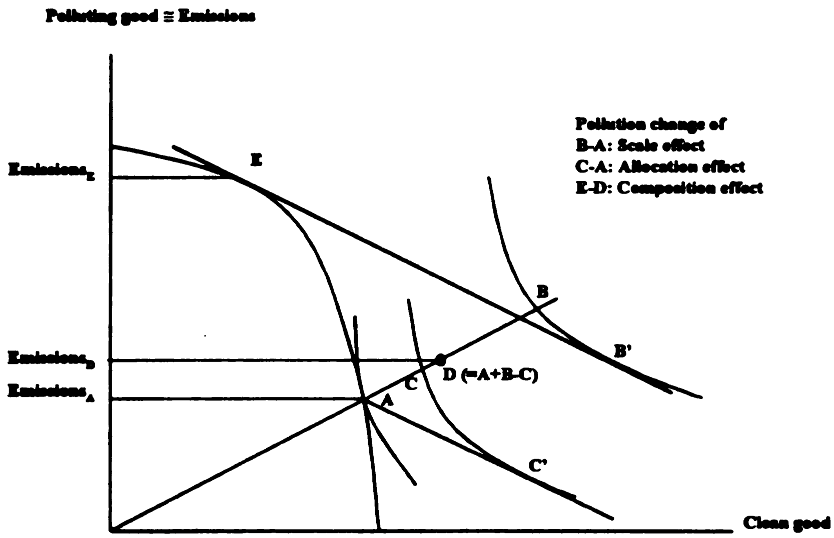
1 + *Output effect* = (1+ *Scale effect*)(1+*Allocation effect*).

5. Composition effect: A) -14.3%; B) + 12.5 %;

Calculation: $\frac{1+TotalPollutionEffect}{1+OutputEffect}-1=A)\frac{1.143}{1.33};B)\frac{1.5}{1.33}$

The various effects (for country B) can also decomposed graphically (Figure 2-4).

Figure 2-4. Environmental effect of trade liberalization: Decomposition into scale, allocation and composition effect



2.4.3. Decomposition with Endogenous regulation level

When changing regulations are incorporated, the calculations are slightly altered (Table 2.4).

Table 2.4: Pollution effect of trade liberalization with endogenous abatement

	Country A	Country B
Pollution Effect	-22.8%	+1.25%
Scale effect	+27.6%	+27.6%
Allocation effect	-6.4%	-6.4%
Composition effect	-14.3%	+12.5%
Regulation effect	-25.0%	-25.0%

The adjusted calculations are:

1. Total pollution effect: A) -22.8%; B) + 1.25 %;

Calculation: $\frac{Emissions_2}{Emissions_0} - 1 = A)\frac{54}{70} - 1; B)\frac{81}{80} - 1$

2. Scale effect: + 27.6%;

Calculation: $\frac{U_3}{U_0} - 1 = \frac{18}{14.1} - 1$

3. Output effect: + 20 %;

Calculation: $\frac{Output_3}{Output_0} - 1 = \frac{36}{30} - 1$

4. Allocation effect: -6.4%; remains constant.

5. Composition effect: A) -14.3%; B) + 12.5 % remains constant.

Calculation: $\frac{1 + TotalPollutionEffect}{(1 + OutputEffect)(1 + RegulationEffect)} - 1 = A)\frac{0.772}{1.2\ 0.75}; B)\frac{1.0125}{1.2\ 0.75}$

6. Regulation effect: -25%; by assumption

Despite the changing output levels, the IO efficiency effect as well as the composition remain unchanged by the inclusion of an income effect. However, this would not hold, if sectors are hit asymmetrically by production losses.

2.5. Preliminary Conclusions

The theoretical considerations in this Chapter showed that the overall effect of trade on the environment depends on a number of mechanisms that often work in opposite direction. A full understanding requires a general equilibrium analysis. This is important in particular for four lessons that can be drawn from the discussion.

First, the political process of regulation setting is an important factor in the trade and environment complex. It can be shown in an analytical model that the income effect on regulatory stringency can fundamentally alter the environmental outcome of trade liberalization. This leads to the formulation of the institutional optimism hypothesis. Clearly, an empirical test of the hypothesis requires an explicit modeling of the political mechanism.

Second, both the industrial flight and the poverty attraction hypothesis require a concentration on the composition effect. An empirical analysis of these hypotheses needs to be able to filter out this effect from the other emission-relevant factors, such as scale and regulation effect.

Third, the previous section showed that the scale effect and the output of the economy are not identical. Therefore, a focus solely on the scale effect overestimates the pollution impact of pollution. Instead, an input based indicator of pollution intensity is needed. In particular, in the context of trade the allocation efficiency effect that determines the difference between scale and output effect can be substantial.

Fourth, interactions between increased requirements for abatement are complex. On the one hand, higher production costs can reduce output, and might cause firms to relocate. On the other hand, the reduced externalities increase the potential total output of an economy. They also might have a feedback on the composition of the economy. An explicit modeling of these mechanisms is also desirable.

A full understanding of these interactions requires a complex model. It will be shown in the next Chapter that a CGE model is best suited for this purpose. The model developed in the next Chapter will address these four important issues.

CHAPTER 3

MODELING TRADE AND ENVIRONMENT IN A GENERAL EQUILIBRIUM FRAMEWORK

3.1. Empirical Modeling Approaches

The previous chapters have presented a considerable complexity concerning trade and environment interactions. The first part of this chapter describes and evaluates different methodological approaches that are available for an empirical analysis of the various trade and environment hypotheses. It will justify the choice of a computable general equilibrium analysis for the present study. The model itself is developed in the second part of this chapter.

Ideally, an empirical analysis ought to integrate the important feedback mechanisms to the largest possible extent. No empirical method takes account of all such mechanisms. However, a few approaches could provide fruitful insights in understanding and quantifying the various relationships. One can organize these approaches into three major groups. A first way of exploring the trade and environment relationship is the case-study approach; the second approach is to econometrically estimate the pertinent relationships; thirdly, one can apply economic simulation models, especially computable general equilibrium (CGE) models. The distinction among these three approaches is in practice not quite as sharp as the taxonomy might suggest. Simulation models, for instance, rely on econometric estimates or use estimates derived from case studies. Depending on the case at hand, it is possible or even advisable to adopt hybrid approaches. Nevertheless, for a full appreciation of the choices in empirical modeling it is useful to examine briefly the three basic approaches.

3.1.1. Econometric Approaches

Some econometric studies of the trade-environment relationship were discussed in previous chapters. They focus either on trade flows or on foreign direct investment, and relate them to indicators of environmental stringency. As discussed previously, despite some progress in understanding the problems, these studies fail to firmly establish a conclusive link between environment and trade. Although the econometric approaches have a rigorous theoretical framework, the available data are generally too weak to allow a conclusive estimation. Statistical difficulties appear at numerous levels.

1. Testing the Heckscher-Ohlin theory

The Heckscher-Ohlin theory of comparative advantage, on which much of the argument in the previous two chapters rests, is difficult to prove empirically, although it remains the most important theoretical framework in international economics. Notably, it took several decades to solve the so-called Leontief paradox. In his seminal article, Leontief (1954) showed that the capital-redundant United States apparently exported labor-intensive goods. The article sparked an abundant literature that either developed theoretical modifications to the simple Heckscher-Ohlin model (e.g., the inclusion of product cycles) or pointed out biases in the data construction (e.g., the assumption that imports use the same production technology that is used in the U.S.). Also it is difficult to get pre- and post-trade prices.

Naturally, an analysis of the significance of the environmental stringency in determining trade flows will be even more difficult than the analysis of labor and capital endowment. Furthermore, a time series analysis of one country would need to include environmental policies in the main trading partners. An increasing regulatory stringency of a country does not imply a decreasing attractiveness for pollution-intensive industry, if environmental policies in other countries evolve faster.

2. Measuring environmental stringency of a country

For cross-country comparisons, no clearly identified yardstick for environmental stringency is available. The various possibilities for such an indicator include government outlays on environmental policy; participation in international agreements; abatement expenditure figures; or the number and value of environmental taxes and levies. However, the choice of one indicator over another will skew the result, because preferences vary among countries for certain types of instruments (e.g., taxes or regulations). Similarly, the official regulatory framework may not be supported by actual enforcement, key industries may be exempted from regulation or taxation, or inefficiencies in the environmental policies may make the same pollution reduction much more costly in one country than in another.

3. Measuring abatement costs in a sector

Also at the firm or sector level, a number of potential indicators of regulatory costs exists, such as abatement expenditures, the number of inspections, the amount of environmental taxes paid, and the number of regulations. These measurements, too, can only be a proxy of the actual importance of environmental policy for a firm's operation. First, there may be a large gap between the letter of the law and what is actually enforced. Second, the cost-effectiveness of an environmental policy can vary substantially. In the extreme case, the actual cost of the abatement itself could be nearly zero while the administrative burden to prove that the abatement took place could be quite high. Also, if one country achieves the abatement reduction via a regulation but another via an ecotax, the regulated company is likely to have a competitive advantage over the taxed one, which in addition to its abatement costs has to pay taxes for the non-abated emissions. The taxed enterprise would react more sensitively to environmental policy than the non-taxed one.

4. Measuring pollution

On the output side, that is, concerning the pollution level itself, difficulties lie not only in measuring pollution levels but also in defining meaningful ways of aggregating a multitude of different pollutants. Solutions to these problems often need to be found on a case by case basis. For instance, various indicators of environmental stringency could be compared using sensitivity analysis. An alternative could consist in aggregate indicators based on *ad hoc* weighting methods, toxicity weights, hedonic values, or principal-component analysis. Unfortunately, often even the basic elements of such an index construction are hard to come by, as data collections of environmental factors exist only fairly recently. A full time-series analysis is therefore often impossible.

5. Deriving an abatement function

A further statistical difficulty lies in deriving an abatement function. General data problems are exacerbated by the fact that environmental regulations are rarely relaxed but only increase in stringency. Therefore, regulations follow a common trend with technological process. This common trend means it is often not clear whether a change in the emissions is due to increased environmental stringency or to unobserved technological processes, because multicollinearity is likely to plague the analysis.

6. Simultaneous equations

As was discussed in Chapter 2, environmental stringency cannot be taken as exogenously given. This relationship requires the estimation of a system of simultaneous equations to establish cause and effect. Pitfalls in establishing causality also exist in other areas. For instance, one could falsely interpret low abatement expenditures (in dollar terms) as having lax environmental standards in country. In reality they might be the result of a very cost-effective environmental policy, or in the extreme, the result of a policy that leads to an exodus of pollution-intensive industries. Similarly, the opening of a country to trade might increase the relative importance of differences in environmental regulations, but improve technology dissemination.

If one adds to these issues just discussed, problems of imperfectly operating markets, exogenous shocks, or rigid prices, it is clear that an econometric analysis of trade and environment relationships is difficult. In practice, it is likely to remain limited to testing simple relationships, for instance, the direction of trade and investment as a function of an index of regulatory stringency. Many more complex interactions are beyond the reach of econometric methods until the data situation improves substantially.

3.1.2. Case Studies

The division line between econometric approaches and case-study approaches is not sharp, because the data of an econometric study also ultimately derived from individual cases. However, a change in focus warrants a distinction. Econometric analysis concentrates on the formulation and testing of falsifiable hypotheses, and applies standard statistical criteria to do so. Evidently, this approach can also be followed within a case study. However, for the case-study approach, as it is understood here, it is possible to remain purely descriptive or operate with simple inspection of data. For the issue at hand, sectoral or historical country studies could provide suggestive insights.

3.1.2.1. Sectoral Studies

The advantage of the sectoral case-study approach is that it allows us to look intensively at the obvious candidates where environmental factors might play a role (one could think here of chemicals, metal production, etc.) and which are of great concern from a policy point of view. For these, it would be necessary to identify the various technological options and collect data on their respective cost structure and environmental impact. One would then need to detect to what extent regulations or other factors determine the sector's size and technological development. One could place the study by Wheeler and Martin (1992) into this category. The authors analyzed the dissemination of pulp production technology as a function of a country's openness to trade. They could show that economies that are more open generally have the more advanced (and clean) technology.

However, it is questionable whether the experience in one sector is anecdotal or can be generalized, because there is a risk of a selection bias when choosing the sector. Further drawbacks are the potential need of considerable data, in particular at the firm level, that might make many potentially interesting cases impossible to conduct in the first place. In addition, the approach risks leaving important factors out of the analysis, due to the partial nature of the analysis (in particular, those that affect the policy process).

3.1.2.2. Historical country studies

Historical studies of whole countries are one way to avoid the problem of having only a partial (and therefore possibly biased) look at the trade and environment problem. The result of the historical changes that occurred in these countries is then extrapolated and qualified to provide an estimate of the expected impact of a similar change. Hufbauer and Schott (1992) applied this approach for the case of NAFTA. The authors assume an analogy of the North American case with 31 similar countries that have liberalized economically in the past. They derived from these data an approximation for the economic changes induced through the trade liberalization of NAFTA. In theory, it might be possible to collect the corresponding information on environmental factors for at least some of the cases. However, it has not been until fairly recent that organizations, such as the World Bank (especially since the World Development Report 1992), the OECD (1995) and the World Resources Institute (1986), have begun to compile international statistics of environmental indicators. In practice, therefore, one would have to rely to a significant extent on *ex post* construction of data sets, using external information on pollution intensities. Alternatively, one could choose a more descriptive approach based, for instance, on people's perception of the development.

If the difficulties in constructing useful environmental data sets can be overcome, the historical approach could provide useful first-order approximations of the expected impact of trade liberalization on growth and environmental variables. However, problems remain. For instance, the case of NAFTA is fairly unique, because it constitutes a free trade area between a highly industrialized and a fairly poor country. The case that may come closest to the NAFTA is that of the 1986 accession of Spain into the European Community (now European Union).[15] Still, Spain's EC membership differs from Mexico's membership in NAFTA in at least four respects. First, NAFTA does not provide for fiscal support for its poorer member. Second, NAFTA does not allow free movement of labor. Third, the income differences between the

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U.S. and Mexico are a multiple of that between the European nations. Fourth, the European Community has an active policy aimed at harmonizing environmental minimum standards within the Community.

Another critical factor that speaks against using the historical approach to analyze the question of NAFTA's environmental consequences is that it provides little guidance on a disaggregated level, since the composition of any economy is unique. Therefore the historical approach could successfully attain only a good estimate of the scale effect but not the composition effect of trade liberalization on pollution.

3.1.3. Simulation Approaches

Simulation approaches are distinct from both econometric approaches and case studies in that they principally do not need original data. Instead, they rely on constructing economic models with parameter values that are derived from literature reviews of econometric studies, case studies, engineering data, or even educated guesses. With these data, the modeler can analyze the impact of counterfactual policy scenarios.

Simulation analyses have the clear disadvantage that they are inherently incapable of hypothesis testing according to scientific criteria. Their reliance on secondary data means that the modeling assumptions already contain the outcome of the analysis. For instance, if a trade model contains an equation that specifies environment as an important production factor, a simulated regulatory change will automatically lead to a change in the trade pattern. The

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[15] The other countries, Greece and Portugal, that joined the EU in the Southern enlargement (1981 and 1986) are qualitatively different. Both already had largely free-market access, due to an association treaty and EFTA membership, respectively (Shelburne 1993).

scientific argument about the importance of regulation remains limited to a discussion, whether the original assumption is plausible. The discussion is complicated by the fact that a correct specification of one policy aspect can be overwhelmed by an incorrect specification of another essential relationship. This problem is the reason for the unease of many economists with economic simulation models. It is often not immediately clear, which particular equation specification is the driving force of a simulation result. Consequently, simulation models often remain black boxes to the reader, unless a significant amount of time is invested in exploring the modeling details. Unfortunately, therefore, model validation through peer review is often fairly limited.

While suffering from a severely limited model validation, simulation models are often the only method of deriving at least an approximate economic analysis. As discussed data problems are likely to be overwhelming for an econometric approach, if a minimum amount of complexity is required. Simulation models allow a complex analysis while avoiding the data problem by using best available estimates. The importance of individual parameters can be tested using sensitivity analysis. Three types of simulation approaches are available. These are macromodels, input-output analysis, and finally CGE modeling.

Macromodels

Macroeconomic models are based on observed statistical correlation among aggregate variables in the past. They are applications of econometric models, and as such shares some of their problems for the estimation the economy-environment interaction. Therefore, macroeconomic models of trade and environment relationships are forced either to make simplifications in the modeling structure or to impose external parameters into the model structure that are not derived within the same framework as the econometric estimates.

For instance, in the context of analyzing NAFTA, Adams et al. (1992) and Clopper Almon/Inforum (1992) applied macromodels with fairly detailed sectoral disaggregation. However, they do not provide any disaggregated information on the factors of production. An extension of the models to include environment as a production factor is therefore not straightforward. In addition, most environmental data do not exist in sufficiently detailed time series, but are at best available as simple point estimates.[16] While macro-models have been used successfully in many instances to estimate economic effects of trade policies, in analyzing the field of economy-environment interactions, its use is limited.

Input-Output Models

Environment can be integrated in a straightforward way by extending an input-output matrix. On the input side, the environment appears as a source of extraction and provider of recreation for industry and final demand. On the output side, the environment receives discharges of residuals that occur during the production or consumption of a good. Like all other sectors of the I-O matrix, the environmental sector can be further disaggregated, e.g. into air, land, and water.[17]

The first generation of simulation studies are Leontief models that used this type of extended input-output matrix to analyze policy changes (e.g. Rhee and Miranowski 1984).

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[16] On an aggregate level there exists, however, a group of often highly sophisticated KLEM models named after the four included input factors capital (K), labor (L), energy (E) and materials (M). These studies analyzed the possibility of an economy to substitute away from energy dependency after the oil shocks in the 1970s. These models, however, are partial at best, and are of limited value in analyzing the more multifaceted problem complex that we are dealing with.

Victor (1972) provides a comprehensive model of this type for the whole economy. Most other empirical models such as Cumberland and Stram (1976) are restricted to an industry-by-industry format. A survey is presented in Førsund (1985).

The usefulness of traditional input-output modeling is, however, limited by the assumption that all coefficients are fixed. This means that I-O models are generally not useful tools when it is assumed that an economy undergoes structural change, as is the case for trade liberalization. To a lesser extent, the implicit assumption that statistically established structural relationships will continue to hold in the future, vexes also other approaches such as macroeconomic and CGE modeling. However, macroeconomic models allow mitigating this problem through the inclusion of trend variables. By contrast, in input-output analysis the level of pollution only changes through alterations in the composition and magnitude of consumption, or some arbitrary change in the pollution coefficients over time. Input-output analysis therefore usually overestimates the effects of policy measures, since it does not allow for substitutions that may mitigate the impact of the parameter changes. Input-output calculations therefore could only serve as an upper bound of plausible values. Any conclusions resulting from an extrapolation of these results would have to be qualified.

Computable General Equilibrium Models

Computable general equilibrium (CGE) models are hybrids of macromodels and input-output models, combining the advantages of both. The CGE approach involves the construction

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[17] Ahmad, El Serafy, and Lutz (1989) and Costanza (1991) contain papers on the issues involved in producing environmental accounts.

of a model that explicitly incorporates theoretical assumptions about the behavior of individual actors. Most of the assumptions used in standard models are the usual and widely accepted staple of economic theory. CGE models generally postulate that firms maximize profits subject to constraints set by technology, prices, interest rates, and so forth, and that the behavior of consumers is determined by utility maximization subject to price and income constraints. These basic assumptions are usually extended to serve the intention of the modeler. Modeling economy-environment interactions, for instance, requires some explicit assumptions about the form in which this interaction takes place. Many CGE models use statistical estimates for the fundamental theoretical parameters. The missing parameters are obtained through calibration (cp. Shoven and Whalley 1992). This approach means they are chosen in such a fashion that the model reproduces a historical data set, called a Social Accounting Matrix (SAM), constructed for the purpose of the model. Therefore, CGE models use both point and time-series estimates to derive behavioral parameters. However, the difference between macromodels should not be overestimated (cp. CBO 1992, p. 68). Econometric models can be regarded as analogous to a reduced form of the more explicitly modeled CGE models, although some differences remain.

The flexibility that CGE models provide in analyzing complicated economic interactions has led to their wide application in the fields of trade and public finance with a special interest in the distributional impact of macroeconomic policy (Robinson 1989; Shoven and Whalley 1992). Some CGE models analyze the economic costs of environmental regulations at the regional level, and at the national and international level, mainly with a focus on the economic effects of reducing CO_2 emissions. Hoeller, Dean, and Nicolaison (1990), and Nordhaus (1991) provide surveys of this kind of modeling. Some more recent examples are given by

Hazilla and Kopp (1990), Jorgenson and Wilcoxen (1990), Bergman (1991), Boyd and Uri (1991), Conrad and Schroeder (1993), Ballard and Medema (1993), Nestor and Pasurka (1993), and Perroni and Wigle (1995), Beghin et al. (1995), Copeland and Taylor 1995; Smith and Espinoza 1996), Dessus and Bussolo (1998).

The advantages of the CGE approach made it also the prime choice for modeling the effects of NAFTA (CBO 1992). At least two dozen CGE models deal with various aspects of trade liberalization on the Mexican economy, none of which focuses on the environment. Reviews are provided in Shiells and Francois (1994), Brown (1992), and CBO (1993).

Table 3-1 summarizes the pros and cons of the three main empirical approaches. The overwhelming arguments in favor of a CGE model are its manageable data requirements and its analytical flexibility.

Table 3-1. Comparison of different empirical approaches to assess trade and environment interactions

	Econometric Studies	Case Studies	Simulation /CGE models
Data Requirements	• high, problems of multicollinearity • difficulties in constructing proper indices	• medium • selection problem • use of micro- and macro-data possible	• low • use of best econometric estimates
Complexity of analysis	• simple, partial analysis	• complete analysis possible • could include policy	• high • allows experimental forms
Hypothesis testing	• yes • estimation of confidence intervals	• focus on obvious candidates • descriptive • low generalizability	• not truly possible, results driven by assumptions • can filter out key relationships • sensitivity analysis
Required work load of analysis	• mainly data construction	• needs detailed firm level or institutional knowledge	• high, if model is built from scratch
Existence of literature	• few, inconclusive	• some	• plenty concerning trade relationships and environmental relationships

3.2. Non-Technical Model Description

For the purpose at hand, the arguments overwhelmingly favor the employment of a CGE model for the analysis. However, even after deciding to use a CGE approach, there are an infinite number of variants possible. These concern especially the representation of the environmental component, the details of the tax system, the labor market, the government sector, the level of sectoral disaggregation, and the supply of production factors. Ideally, one would want to have a model that is as complete and accurate as possible. In practice, a cost-benefit calculus guides model construction. While the skill of the modeler, the existence of other models, and data availability influence this calculus, it is primarily driven by the analytical focus. In the case at hand, it is evidently important that the environmental aspects of the model are included in a careful manner. Clearly, however, in some cases difficult choices have to be made. In the case hand, geographical differentiation and the aspect of income distribution (which is important for its influence on regulation setting) had to be omitted from the analysis. The description of the model utilized in this paper is separated into a technical and a non-technical part, which principally can be read without the other.

3.2.1. Overview

To assess the environmental consequences of trade liberalization empirically, a purpose-built computable general Equilibrium model of the Trade Environment Relationships in North America (ETERNA) will be employed. The newly developed model is comparative-static; it models a single period only. The model distinguishes four regions, namely the three NAFTA countries, Mexico, the United States and Canada, as well as the Rest of the World. Within each

NAFTA country, there exist four agents: firms, consumers, importers, and the government. Output is based on three primary production factors: labor, capital and air pollution.

ETERNA has 26 production sectors, most of which trade products with other regions (Table 3-2). All sectors share a common production structure that is depicted in Figure 3-1. As usual in this type of model, producers choose the optimal combination of inputs to minimize production costs, given the level of sectoral demand and relative after-tax prices. Production in some sectors shows economies of scale. However, ETERNA maintains the assumption of monopolistic competition. This assumption means that all sectors earn zero profits.

Technology is assumed to be such that the decision-making process can be separated into several stages.[18] First, demand for final and intermediate inputs is allocated between imported and domestic supply. This allocation is the so-called Armington assumption, which explains cross-hauling of identical goods (Armington 1969). Second, domestic production results from a combination of value added and intermediate inputs. Third, value added is a composite of labor and production capital. Fourth, value added is associated with the use of an environmental sink. Fifth, the environmental sink is a function of abatement capital and environmental pollution, which in the model includes only air emissions.

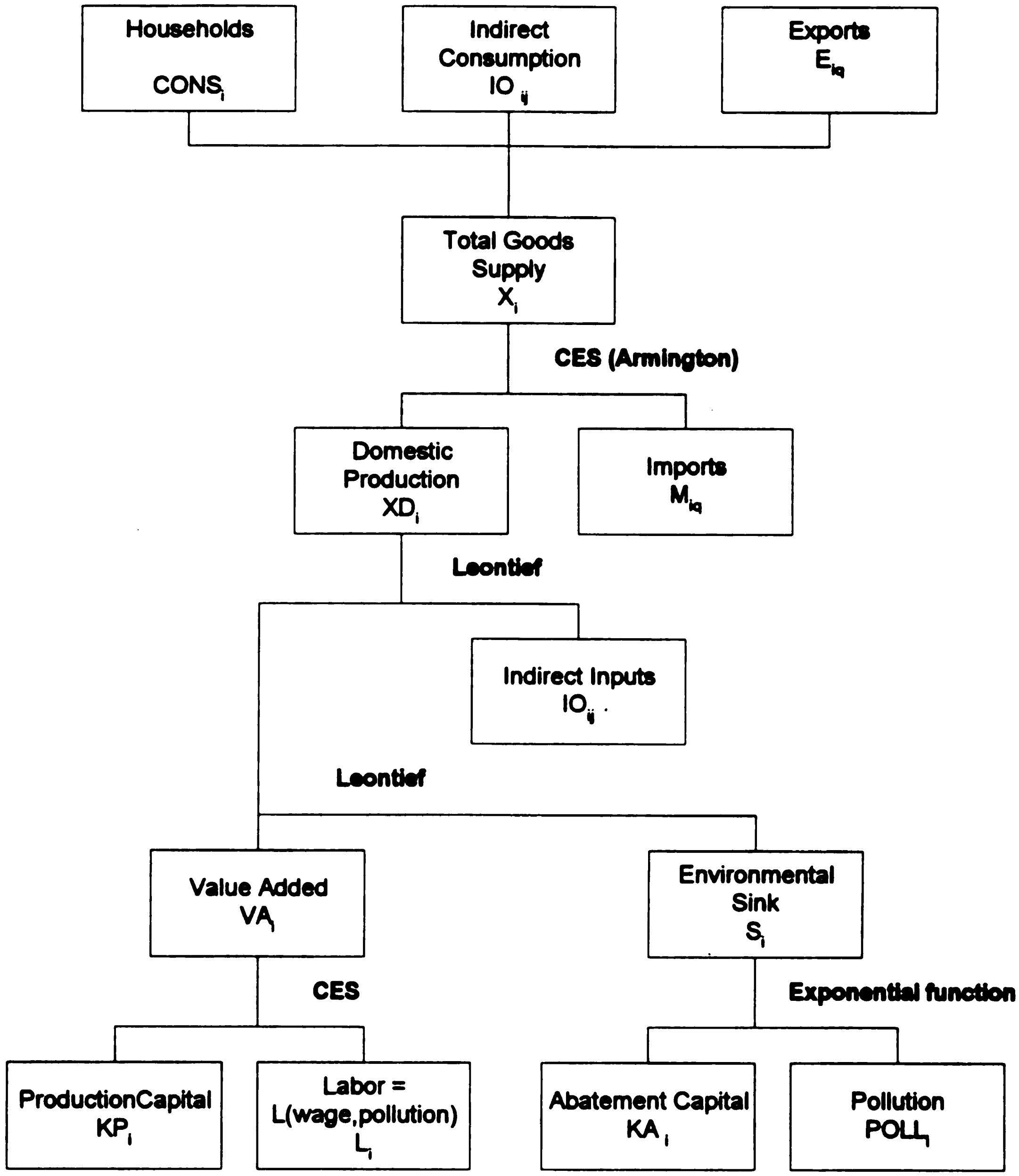
The demand for the sectoral outputs has three components: they are used as intermediate inputs to production, they are exported, and they serve for the final consumption of each country's households, which are modeled as representative agents. Households act as utility maximizers that choose their optimal consumption bundles. ETERNA does not distinguish, as is often done, between consumption and production sectors. Rather, the final consumption of the produced good enters the utility function directly.

[18] All production steps are homothetic with a constant elasticity of substitution, which implies separability among subsets of different input bundles.

Table 3-2. Definition of Production Sectors for North American Social Accounting Matrix

Sector	Description
1. Agriculture	Agriculture; Livestock; Forestry; Fishing & Hunting
2. Mining	Coal products; Metal ore mining; Other mining; Quarrying; Other metal ore mining
3. Petroleum	Petroleum extraction & natural gas; Petroleum products; Basic petrochemical
4. Food Processing	Meat & dairy products; Processed fruits & vegetables; Milling of wheat & their products; Milling of corn & their products; Processing of coffee; Sugar & products; Oils & fats; Food for animals; Other processed food
5. Beverages	Alcoholic beverages; Beer, malt; Soft beverages & syrups
6. Tobacco	Tobacco & products
7. Textiles	Soft fiber textiles; Hard fiber textiles; Other textiles
8. Wearing Apparel	Wearing apparel; Hosiery; Knitted wear
9. Leather	Leather & products
10. Paper	Pulp; Paper products; Printing & publishing
11. Chemicals	Basic chemicals; Fertilizers; Synthetic fibers; Drugs & medicine; Soaps & detergents; Other chemical industries
12. Rubber	Rubber products; Plastic products
13. Non-Metallic Mineral Products	Glass products; Cement; Other non-metallic mineral products
14. Iron and Steel	Steel mills
15. Non-Ferrous Metals	Non-ferrous basic industries
16. Wood & Metal Products	Manufacturing wood; Other wood industries; Furniture; Metallic structures; Metal forging; Other metallic products
17. Non-Electrical Machinery	Machinery & non-electrical equipment
18. Electrical Machinery	Electrical machinery; Electrical appliances; Electronic equipment; Other electrical products
19. Transport Equipment	Motor vehicles; Motor parts; Missiles & tanks; Other transportation equipment
20. Other Manufactures	Other manufacturing industries
21. Construction	Construction
22. Electricity	Electricity, gas & water
23. Commerce, Restaurants & Hotels	Commerce (wholesale & retail trade); Restaurants & hotels;
24. Transport & Communication	Transport; Communications
25. Financial & Insurance Services	Financial services; Dwellings, real estate
26. Other Services	Professional services; Educational services; Medical services; Recreational & cultural services; Other services

Figure 3-1. Structure of the production function in ETERNA



Trade relationships are modeled such that the balance of payments of the different regions does not change. Included here are also the flows from cross-country capital ownership. Demand for exports to a NAFTA country results from an Armington-type demand structure. Exports to the rest of the world follow a constant demand elasticity function, while supply from the rest of the world is perfectly elastic. Trade flows are subject to import duties, which are collected by the government, which recycles them back to the economy in a lump-sum fashion. Non-tariff barriers are a significant obstacle to free trade, which results in rents for the importers. However, it is assumed that these rents do not produce any benefit to the representative agent, and are therefore counted as net welfare losses.

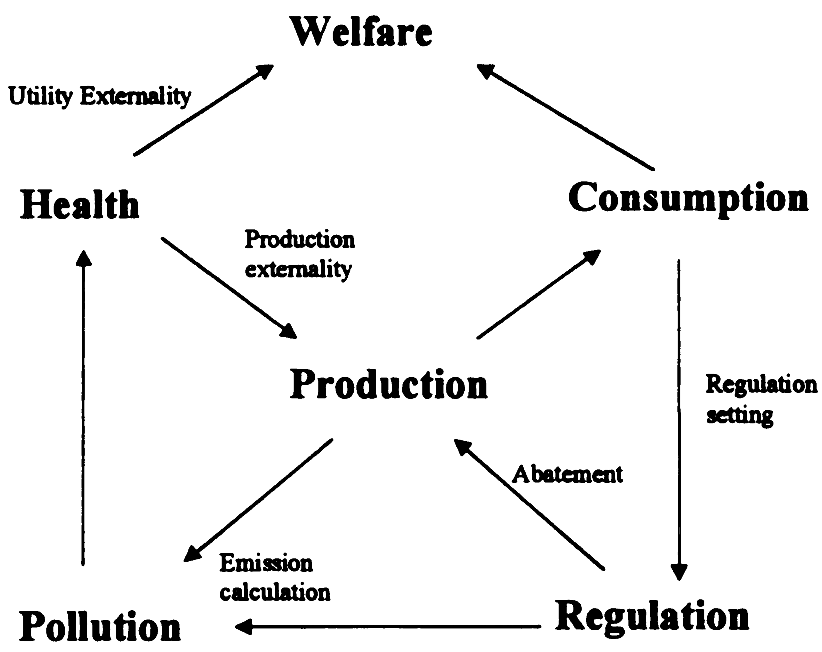
3.2.2 Economy-Environment Nexus in the Model

The important feature of ETERNA is the economy-environment nexus. Five different relationships can be identified:

1. Calculation of emissions
2. Externality in the production function
3. Externality in the utility function
4. Abatement cost function
5. Determination of abatement level

These relationships are shown in Figure 3-2. The numbers in the Figure correspond to each identified relationship. There exists no model that incorporates all 5 aspects. The simplest analysis integrates only the first relationship. This integration can be achieved by use of a standard CGE model of trade liberalization and inclusion of an environmental input-output table as a simple add-on. This approach has been taken by Grossman and Krueger (1995) who use the existing model by Brown, Deardorff and Stern (1992) and calculate the environmental consequences through imputation of U.S. pollution intensity data into the volume of trade. Their results suggest that the environmental consequences of NAFTA will be negligible.

Figure 3-2. Economy and Environment Interaction in ETERNA



Lee and Roland-Holst (1997) analyzed the economic relationship between Japan and Indonesia by imputing U.S. pollution intensities into their mutual trade. Even under the arguable assumption that the pollution intensity of a sector in Japan is not lower than that in Indonesia, the authors find a considerable asymmetry in the pollution content embodied in the exports of the two countries. Indonesia exports pollution-intensive goods and imports goods that are relatively clean. A CGE analysis of the trade relationship points to considerable scope for policy instruments to reach environmental improvement at low costs in terms of GDP. In many respects the economic relationship between the U.S. and Mexico is similar to that between Japan and Indonesia. However, in the North American case, it is not evident that embodied pollution flows from the poorer to the richer country. Bommer and Schulze (1996) who used a similar approach too Lee and Roland-Holst for NAFTA show that in this case the U.S. is a net exporter of relatively pollution intensive goods and becomes more so due the introduction of NAFTA.

The add-on approach provides a straightforward way to organize data for a historical economic situation. However, for the analysis of a counterfactual situation, the approach is too parsimonious. Changes in the pollution level are calculated out of the resulting change in sectoral composition from a model that otherwise completely ignores environmental interactions. This approach is a special case of the more general model that includes environmental feedbacks on production.

Several CGE models consider the effects of regulations on production costs and the consequent changes in output and trade. Although hampered by sketchy data, there exist some interesting approaches for single country models that include representations of emissions abatement functions, for instance, Dessus and Bussolo (1998). A direct application to Mexico can be found in Beghin et al. (1995).

Most of these models are, however, of a partial equilibrium nature in that they only consider the potential costs but not the benefits of environmental restrictions and standards on the national product. This consideration is because benefits and costs of changes in the level of pollution are difficult to obtain. Perroni and Wigle (1995) use an *ad hoc* functional form that measures the welfare increase from a reduced pollution level. Their analysis relies on a separability of pollution damage and consumption in the utility function. The welfare effect thus has no impact on the behavior of the model itself. This outcome means that, effectively, the model is run, and the welfare effect is calculated later.

Ballard and Medema (1993) integrate producer-producer and producer-consumer externalities into a CGE model of the United States. The authors incorporate material damage into the analysis through variable input-output coefficients. This approach allows the researchers to approximate the costs of damaged output due to changes in the pollution level through increases in the demand for intermediate inputs of that affected sector. In addition consumer welfare is affected through a parameter affecting the health of the population. Similar approaches are followed by Copeland and Taylor (1995) and, in a trade, context by Smith and Espinoza (1996)

Pireddu (1996) developed a closed-economy model that includes the first four important environment economy relationships. This approach allows him to test a variety of environmental tax options. His model so far is calibrated only to a primitive "toy" economy. However, in principle, the model could serve as a shell that could be calibrated to actual data.

There are two attempts that are in spirit close to the modeling assumptions described further below. Cole *et al* (1997) add emissions figures to an existing model simulation. A pseudo-regulation function is imposed on their trade model by imposing a U-shasped emision function on top of the results. However, since the environmental Kuznets curve is the result of both structural and regulatory changes, this method inherently leads to a double counting of the structural change. By contrast Strutt and Anderson (1998) add a unit emissions curve that is estimated from surveys While this work provides good detailed technical information, the projected technological progress is not linked to trade, and could therefore be deemed autonomous.

ETERNA fills a gap in the literature by incorporating all five identified economy-environment relationships: The environment is modeled as an input factor. Production that uses this factor results in pollution that damages the health of the population. The use of the environment therefore affects directly the supply of labor in the model. This effect leads to lower production as a result of pollution due to sick days, reduced physical health, etc. The supply of labor is therefore modeled not only as function of the real wage rate but also of the general level of pollution.

The use of the environmental input depends on two factors. First, it is a direct function of the output in the various sectors. If a polluting sector grows without any change in the composition of the inputs, the pollution output increases. (Because ETERNA allows for economies of scale, this increase will not necessarily be in proportion.) The second factor that determines the pollution output is the pollution intensity of production that is allowed by the government.

The government regulates the amount of pollution each sector is allowed to emit per unit of production. Effectively the use of the environmental output also fixes the amount of abatement capital per unit of production. In a further important step, the level of the abatement expenditure has been made endogenous to the model, namely as a function of the real income of the representative agent. The motivation behind this follows the argument outlined in previous chapters that a wealthier population calls for a stricter level of environmental regulation. Therefore, insofar as the policy of a country increases the material well-being of its population, there exists a direct feed-back to the stringency of its environmental regulation. It is therefore not *a priori* clear what direction environmental changes will have in the different countries, because the composition of the economy changes at the same time as the effective supply of the environmental input.

To impute the effect of pollution on well-being (which is not linearly related to increased material welfare), overall welfare therefore takes account of both changes in the material well-being and of health. For this feedback mechanism macro-epidemiological data are employed that show the effects of pollutants on health, sick days, and hence labor supply. However, three other aspects that are not addressed should be mentioned here for completeness sake.

First, the mechanisms of economy-environment interaction, such as technology adoption and are intrinsically dynamic in nature. A comparative static framework glosses over this aspect.

Second, a focus on the income elasticity of regulation neglects the demand side effect and consumption production patterns of higher income. A high demand elasticity for clean product would have an impact on a country's economic composition and reinforce the country transformation. However, many highly income elastic products, such as cars, are also pollution intensive. The analysis further below will however be based on a unitary income elasticity.

Third, even if the analysis shows that country transformation hypothesis holds in a group of countries that liberalize their trade, it cannot be excluded that pollution in third countries increases. As the country with the previously lax regulation level improves its enforcement, the very polluting industry might simply move on to other places to satisfy the larger overall demand.

Next, a more detailed technical description of the equations will be given.

3.3. Model Equations: Technical Specification

In this section, a more detailed and complete description is given of the structure of ETERNA. The calibration process and the data used for the numerical specification of the model will be described further in section 3.

The description of the model equations observes the following notational conventions. Quantities are capitalized (e.g. *XD* for domestic production); prices are in lower case letters (e.g. *pxd* for the price of domestic output); parameters are denoted in Greek letters (e.g. σ for an elasticity) or spelled out completely (e.g. *scale* for the economies of scale parameter). To avoid notational clutter, country indexes are generally omitted, except where they are necessary to describe bilateral relationships.

Indices used in the description are

i	production sectors (subscript)
k	countries (subscript)
q	foreign countries (subscript)
w	world (subscript)
n	net of taxes (superscript)
g	gross of taxes (superscript).

3.3.1. Production

A difficult problem for CGE models is to specify the production function. Like most models, ETERNA assumes a functional form with convenient mathematical properties, in particular constant elasticities of substitution. As described in the introductory section, in each country, production technology in the 26 sectors follows a nested structure. In all industries, a fixed-coefficient matrix (Leontief function) is used in the top nest for intermediate values and the value-added composite. The relationship fixes the relative proportions of the inputs. For total output, however, ETERNA allows for scale economies, as outlined in the following equation:

$$3.1 \qquad XD_i = \left(min(\sum_j io_{ij} X_j, VA_i) \right)^{scale_i}$$

where

XD_i = domestic production of good i,
io_{ij} = intermediate input parameter of good X_j into production of good i,
VA_i = value added for production of good, and
$scale_i$ = elasticity expressing economies of scale associated with sector i.

In the second nest, value added is produced in a constant-elasticity-of-substitution (CES) production function, using labor and a capital-environmental sink composite.

$$3.2 \qquad VA_i = CES(KS_i, L_i) = \varphi_i \left(\beta_i KP_i^{\frac{\sigma_i - 1}{\sigma_i}} + (1 - \beta_i) L_i^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}},$$

where

KP_i = production capital,
L_i = labor used in production sector i,
φ_i = scaling parameter,
β_i = share parameter, and
σ_i = elasticity of substitution between labor and capital-sink composite.

The third nest is defined as a fixed-coefficient relationship between the use of directly productive capital in the sector and the environmental sink function. The rationale for this function is that every production process not only consumes material inputs but also produces undesired byproducts that need to be removed from the production process by a sink. Technically, this is a production output. Mathematically, however, this component to the production function can be defined as an input.

$$3.3 \qquad S_i = s_i VA_i$$

where

S_i = sink function, and
s_i = proportionality parameter.

The sink again is a combination of two factors. The sink function can be fulfilled either by emitting the by-products of the production process directly into the environment, or by installing abatement equipment (e.g., scrubbers). The sink follows a constant elasticity function:

3.4 $$S_i = A_i KA_i^{\zeta}$$

where

A_i = emission of air pollutants
KA_i = pollution abatement capital employed in sector i
ζ = positive parameter between 0 and 1.

Abatement expenditure therefore yields decreasing returns to scale. An increase in abatement expenditures by 1 percent leads to a reduction in emissions by ζ percent.

The total capital employed in production can be defined as the sum of its components, productive and abatement capital:

3.5 $$KT_i = KA_i + KP_i$$

The usual profit maximizing conditions apply. At each production level, therefore, the costs of the inputs equal the value of the outputs, which translates into the following two demand functions for labor and capital:

3.6 $$L_i = \frac{1}{\varphi_i}\left(\beta\left(\frac{(1-\beta)r^{g}}{\beta w}\right)^{1-\sigma} + (1-\beta)\right)^{\frac{\sigma_i}{1-\sigma_i}} VA_i$$

3.7 $$KT_i = \frac{1}{\varphi_i}\left((1-\beta)\left(\frac{\beta w}{(1-\beta)r^g}\right)^{1-\sigma} + (1-\beta)\right)^{\frac{\sigma_i}{1-\sigma_i}} VA_i$$

In equilibrium, profits will be zero. At the top nest of the production function, therefore,

3.8 $$pxd_i^n XD_i = \sum_j px_j^g IO_j + wL_i + r^g KT_i$$

where

pxd_i^n = net price of domestic production in sector i;
px_j^g = gross price for intermediate inputs (a composite of domestic production and imports);
w = wage rate; and
r^g = gross return on capital.

It should be noted here that the production input of emissions does not appear in the equation, because it is a free good that can be used by the firm without charge. However, as will be explained later, the use of the environmental resources is not unlimited. For value added, analogously, the formula can be derived:

3.9 $$pva_i^n VA_i = wL_i + r^g KT_i$$

3.3.2. Households

Households are assumed to have homothetic utility functions and are therefore modeled as a single representative agent. The consumer's decision problem is simplified in this model due to the absence of intertemporal decisions. No saving takes place. All the consumer's income is spent. Total welfare results from two components, namely material well-being, and a parameter reflecting the health of the population. Neither leisure nor saving enter the consumer welfare directly, as is often assumed in CGE models. This simplification has some implications for the factor supply, as will be elaborated below. The relationship assumed here between health and material welfare is of a simple multiplicative nature.

$$3.10 \qquad TOTU = \mathrm{MATU}\left(\frac{\mathrm{HEALTH}}{\mathrm{BASEHEALTH}}\right)^{\pi},$$

where

TOTU = total welfare of representative agent;
MATU = well-being due to consumption and leisure;
HEALTH = health of the population due to the quality of the environment;.
BASEHEALTH = base health of the population due to the quality of the environment; and
π = valuation of health.

This relationship means that the valuation of health increases with the general welfare of the population. The demand elasticity of health with respect to total welfare is one. In principle, the functional form could be chosen such that it contains a higher elasticity. The simple form has been chosen here for three reasons. First, the expected changes in total welfare are not enough to make a major difference between a linear or non-linear functional form. Secondly, and more important, health is a multifaceted concept, that is represented here in a simple linear relationship, namely, the number of days an average citizen is not ill. At an aggregated level, the data situation is not adequate to justify choosing a more complicated functional form. Thirdly, in ETERNA, health cannot be chosen directly by the agent. This restriction means that total welfare is only a reporting variable, rather than a decision variable. Therefore, even with a different functional form, the equilibrium outcome of the model would not change.

The valuation parameter π allows a calibration of the welfare function that provides directly the monetary equivalent of any change in the health of the population. Health is affected by the total pollution output of the country's economy.

3.11 $$HEALTH = 1 - \eta \sum_i A_i$$

where

η = positive parameter.

In other words, health decreases as pollution increases, and it does so in a linear fashion. ETERNA assumes that this relationship is not affected by sector specific increases in expenditures, in particular in health care (which is not contained in the model as a sector), that might mitigate the impact pollution has on health. It is, however, possible to interpret Equation 3.10 to include implicitly the welfare-decreasing aspect of increased health-care expenditures. Furthermore, equation 3.11 implies that there are no cross-country pollution effects. All pollution is therefore assumed to be local.

Consumer behavior is defined as welfare maximization of U, which is defined as

3.12 $$MATU = CES(CONSU, LEISURE) = \left(\psi CONSU^{\frac{\tau-1}{\tau}} (1-\psi) LEISURE^{\frac{\tau-1}{\tau}} \right)^{\frac{\tau}{\tau-1}}$$

where

$LEISURE$ = Leisure
$CONSU$ = utility derived from consumption
ψ = share parameter
τ = elasticity of substitution between leisure and consumption of goods.

The welfare component due to pure consumption is defined as

3.13 $$CONSU = CES(\sum_i CONS_i) = \left(\sum_i a_i CONS_i^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

where

$CONS_i$ = consumption of good i,
α_i = share parameter, and
ρ = elasticity of substitution between the various consumption goods.

Consumers behave as welfare maximizers. Consequently, the demand for consumption goods is

$$3.14 \qquad CONS_i = \frac{a_i^{\frac{1}{\rho}} INCOME}{px_i^{g\,\rho} \sum_j a_j^{\frac{1}{\rho}} px_i^{g(1-\rho)}}$$

where

INCOME = national income.

In contrast to many models of this sort, there exists no distinction in welfare terms between private consumption and government consumption. Both are assumed to contribute equally to the welfare of the representative agent. Consumption is bound by a budgetary constraint.

$$3.15 \qquad \sum px_i^g CONS_i = INCOME$$

Income of the representative agent itself stems from factor income and public transfers.

$$3.16 \qquad INCOME = w^n L + r^n KH + \sum_q r_q^n K_q + TRANSFERS,$$

where

KH = domestic capital owned by the home country
K_q = capital owned by domestic agents in foreign countries
TRANSFERS = government transfers.

The factor income is separated into wages as well as capital income. To incorporate information on cross-country capital ownership, an explicit distinction is made here between capital owned by a country, and capital employed in a country.

3.3.3. Regulation Setting and Supply of Productive and Abatement Capital

The total supply of capital is assumed to be constant. As was touched upon briefly when discussing the welfare function, saving is not part of the utility function. Capital formation is therefore not endogenous to ETERNA, but is assumed to be fixed. Capital can be used either directly for production or can be used for abatement. It is assumed to be completely mobile between sectors. At least in the base model, however, it is not mobile between countries. The pre-existing cross-country capital ownership patterns persist.

3.17 $$\sum_i \left(KA_i + KP_i\right) = K$$

where

K = total capital in the economy.

Total capital is owned either by domestic agents or foreigners:

3.18 $$\sum_q K_{-q} + KH = K$$

where

K_{-q} = capital owned by foreigners in the domestic country

In principle, the supply of pollution is unlimited, with no direct constraint applying to it. However, two components limit its use. The first one was already elaborated upon in the production function in equations 3.3 and 3.4. These two equations outline that the total demand for the sink function is related to the capital intensity of production. Furthermore, there is a substitution relationship between pollution and the amount of capital spent on abatement. Without imposing any costs on the environment or constraining its use otherwise, pollution would be driven to infinity. Therefore, the model needs a mechanism to limit its usage. In practice, in most cases, environmental pollution is limited *via* regulation that prescribes the use of certain pollution abatement equipment. More rarely is its use limited *via* a price mechanism. Whichever of the two methods is applied, in mathematical terms the result can be expressed in terms of a tax equivalent that leads to an identical allocation of abatement and productive capital. In parallel to the discussions in earlier chapters, the allowed pollution intensity is seen as a function of the material well-being of the country. Therefore the use of abatement capital is determined by the following equation

3.19 $$\frac{KA_i}{KT_i} = \frac{KA0_i}{KT0_i} MATU^{\epsilon}$$

where

$KA0_i$	= abatement capital in base case,
$KT0_i$	= total capital in base case, and
ε	= positive number (income elasticity of regulatory stringency as a function of per capital utility).

This relationship could also be interpreted as an implicit tax on the productive capital that is used for the abatement of the environmental pollution. The institutional arrangement is such that the government does not attempt to equalize the marginal abatement costs across sectors, but changes the stringency of regulation across the board. This unequal regulating of various sectors may be the result of limited information on side of the government or political pressure.

3.3.4. Labor Supply

Labor input to the individual sectors is limited by the overall supply of labor in the economy.

3.20 $$\sum_i L_i = L$$

This equation means that ETERNA employs the full-employment assumption. All unemployment in the model is therefore voluntary. The supply of labor is derived from utility maximization that derives the demand for leisure. If we take the total endowment with time as:

3.21 $$TIME = LABOR + LEISURE$$

3.22 $$LEISURE = \frac{(1-\psi)MATU}{w^{n^{\tau}}\left((1-\psi)w^{n^{1-\tau}} + pmatu^{1-\tau}\right)}$$

where

pmatu = marginal utility of income

Furthermore, labor supply increases with the real wage rate that is reflected in the parenthesis of the equation. *pmatu* denotes the true cost of living index, and is defined as

3.23 $$pmatu = \left(\sum_i a_i PX_i^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$$

LABOR is to be understood here as the time spent working. Its productivity is assumed to be also a function of the health of the population, according to the following functional form:

3.24 $$L = LABOUR \cdot HEALTH$$

It is therefore assumed that the health of the population has an effect not only on the well-being, but also directly on the productivity of its labor.

3.3.5. Trade

Final consumption, exports, and intermediate inputs are a composite of domestic and imported products. Mathematically, this the composite good is be described as an Armington aggregation, which means that a CES function combines imports and domestic production:

$$3.25 \qquad X_i = CES(XD_i, \sum_q M_{iq}) = \lambda\left(\mu_i XD_i^{\frac{\delta_i - 1}{\delta_i}} + \sum_q \mu_{iq} M_{iq}^{\frac{\delta_i - 1}{\delta_i}}\right)^{\frac{\delta_i}{1-\delta_i}}$$

where

X_i = Armington composite of good i in country k,
M_{iq} = Imports of good i into country k from country q,
λ = shift parameter,
μ_i = shares of domestic production,
μ_{iq}, = share of imports, and
δ_i = elasticity of substitution.

An Armington function is chosen because, otherwise, the model may provide the unrealistic result of a complete production concentration of a certain sector in just one country. The derivation of the Armington aggregate can be treated completely analogous to the CES production functions described above. Demand for domestic production and imports, respectively, can be derived as:

$$3.26 \qquad M_{iq} = \frac{1}{\lambda_i}\left((1-\mu_{iq})\left(\frac{\mu_{iq} pm_{iq}^g}{\mu_i pxd_i + \sum_k \mu_{ik} pm_{ik}^g}\right)^{1-\delta_i} + \mu_{iq}\right)^{\frac{\delta_i}{1-\delta_i}} X_i$$

$$3.27 \qquad XD_i = \frac{1}{\lambda_i}\left((1-\mu_i)\left(\frac{\mu_i pxd_i}{\sum_q \mu_{ig} pm_{iq}^g}\right)^{1-\delta_i} + \mu_i\right)^{\frac{\delta_i}{1-\delta_i}} X_i$$

Zero-profit conditions result similarly in the following price definition:

$$3.28 \qquad px_i^n X_i = \sum_q pm_{iq}^g M_{iq} + pxd_i XD_i,$$

where

px_i^n = net price of Armington composite,
pm_{iq}^g = gross price of imports from country q, and
pxd_i = price of domestically produced goods.

In the field of trade, a set of identities needs to hold for the bilateral relationships. Exports from country k to country q must equal imports of country q from country k. Therefore,

$$3.29 \qquad E_{ikq} = M_{iqk}$$

where

E_{ikq} = exports of good i from country k into country q; and
M_{igk} = imports of good i by country q from country k.

Equally, export prices of country k must equal net import prices of country q:

$$3.30 \qquad pe_{ikq} = pm_{iqk}^n,$$

where

pe_{ikq} = price of exports of good i from country k into country q, and
$pm^n{}_{iqk}$ = net price of imports of good i by country q from country k.

The goods supply from the rest of the world is assumed to be perfectly elastic. Similarly, the exchange rates of all countries are fixed in international currency, leading to the equation:

$$3.31 \qquad pm_{iw}^g = EXR$$

where

EXR = exchange rate of domestic currency expressed in terms of international currency.

On the other hand, demand of domestic products by the rest of the world follows a constant elasticity function that is driven by the real export price.

3.32 $$E_{iw} = E0_{iw}\left(\frac{pe_{iw}}{EXR}\right)^{v}$$

where

ν = demand elasticity of the rest of the world.

The balance of payments of each country is defined as:

3.33 $$BOP_k = \sum_i \sum_q \left(pe_{iq} E_{ikq} - pm^{n}_{ikq} M_{ikq}\right) + \sum_q \left(r_q \kappa_{kq} - r_k \kappa_{qk}\right),$$

where

BOP_k = balance of payment of country k, and
K_{kq} = capital in country q owned by country k.

The first component lists the real trade flows, while the second component denotes the capital balance between the countries. In equilibrium, the sum of the external balances will be zero.

3.34 $$\sum_k BOP_k = 0$$

3.3.6. Taxes and Government

The government fulfills three functions. It collects various taxes and duties, it purchases goods, and redistributes revenues in the form of transfers to households. Taxes included in

ETERNA are value-added taxes, sales taxes, taxes on capital, and labor taxes, resulting in the following four equations:

3.35 $$pva_i^g = pva_i^n\left(1 + tva_i\right)$$

3.36 $$px_i^g = px_i^n\left(1 + tx_i\right)$$

3.37 $$r^g = r^n\left(1 + tk_i\right)$$

3.38 $$w^g = w^n\left(1 + tl_i\right)$$

Imports are subject to *ad valorem* tariffs, with tm_{iq} denoting the tariff on product type i from country q. Further, non-tariff barriers are also taken into account. They are similarly expressed in their *ad valorem* equivalents, as tn_{iq}. Using these values, the prices paid by the consumer for imports are:

3.39 $$pm_{iq}^g = pm_{iq}^n\left(1 + tm_{iq} + tn_{iq}\right)$$

The practical difference between *tm* and *tn* is that the revenues generated by *tm* are recycled back to the economy as government consumption (benefiting also the consumer). By contrast, *tn* is modeled as complete welfare loss due to rent-seeking behavior, following Anne Krueger's argument (Krueger 1974).

3.40 $$IMPORT\ LOSS_I = tn_{iq}M_{iq}$$

Government provides a public good according to the formala:

3.41 $$PUBGOOD + CES\left(\sum_i GOVCONS_i\right) = \left(\sum_i \omega_i GOVCONS_i^{\frac{\vartheta-1}{\vartheta}}\right)^{\frac{\vartheta}{\vartheta-1}}$$

where

PUBGOOD	= public good,
GOVCONS$_i$	= government consumption of good i,
ω_i	= share parameter, and
ϑ_i	= elasticity of substitution between the various government consumption goods.

The provision of the public good is assumed to stay constant for all scenarios.

$$3.42 \qquad PUBGOOD = \overline{PUBGOOD}$$

Because of this condition, the supply of the public good does not enter the welfare function of households. The tax revenues that are not consumed to produce the public good are recycled back into the economy *via* transfers.

$$3.43 \qquad \begin{aligned} TRANSFERS = &\sum_i \sum_q tm_q M_q + \sum_i tva_i VA_i + \sum_i tx_i X_i \\ &+ tk\,K + tl\,L + \overline{BOP} - \overline{PUBGOOD} \end{aligned}$$

where

$\overline{BOP}$ = balance of payment in base year

The government transfers include also the balance of payments in the base year, which is assumed to be unchanged. This assumption has implications for the closure of the model. Consistent with the assumption of no household saving, the government deficits are netted out in the model.

3.3.7. Closure

A final set of equations is needed in order for Walras's Law to hold. In other words, in equilibrium, the system is not allowed to have any excess supplies. Therefore the supply of the Armington aggregate must equal its demand:

$$3.44 \qquad X_i = \sum_j io_{ji} XD_j + CONS_i + GOVCONS_i + \sum_q E_{iq} + IMPORT\ LOSS_i$$

The supply can be used either domestically (as final consumption and as intermediate input) or for export. This flexibility implies that the system is balanced *via* trade, or, more precisely, with a fixed balance of payments *via* the export prices.

Since all supply and demand functions in the model are homogenous of degree zero with respect to prices, only relative prices are important for the determination of quantities of goods supplied and demanded. All prices therefore need to be deflated by a numéraire. In ETERNA, this was chosen to be the international price level of goods.

3.45 $EXR = 1$

This final equation completes a full description of the mathematical relationships that define the model. However, the behavior of the model depends crucially on the parameter values that are used for the numerical analysis. Chapter 4 will discuss the data on which ETERNA was calibrated.

CHAPTER 4

DATA DESCRIPTION AND MODEL CALIBRATION

This chapter describes the calibration of the ETERNA model described in Chapter 3. A first part presents the social accounting matrix employed. It also presents some stylized facts of the NAFTA economies. The data presented in this part are of little originality and overlap significantly with those used by Roland-Holst et al (1994).[19] These data are sufficient for constructing a standard CGE model. Since the contribution of this paper consists mainly in adding an environmental modeling component, the construction of the environmental data needs to be described more extensively in a second part. This part also serves to outline the rationale for those modeling choices that are inherently data driven.

4.1 Stylized facts of the North American Free Trade Area

4.1.1. Social Accounting Matrix

As the most important data source, ETERNA uses the social accounting matrix (SAM) that was compiled by Reinert, Roland-Holst and Shiells (1993). The SAM is a statistical compilation of the flow of funds situation for the three NAFTA countries. Unless stated otherwise, the discussion below refers to the data in this SAM, which reflects the situation in

[19] Deviations from their approach have been chosen only for modeling convenience, and do not represent a substantive criticism of their paper. However, they are responsible for some divergence in the sectoral composition of the modeling results reported in Chapter 5.

1988, which is the base year for the analysis. The year is chosen because it lies before the implementation of CAFTA.

Since the model follows the creed that the benchmark data reflect an economy in equilibrium, every dollar of the flows of funds is interpreted as an efficiency unit with a price of 1. This interpretation is different from observed physical units, but reflects various qualities of the inputs. For instance, if the wages in one sector or one country are higher than in another, it is assumed that this difference represents higher productivity. Implicitly this means that there is a perfect substitution between 10 workers earning 1 dollar an hour and one worker earning 10 dollars.

The SAM provides information on the money flows in the base year for a number of variables, namely domestic production (*XD*), consumption (*CONS*), input-output relationships (*io*), imports (*M*), exports (*E*), balance of payments (*BOP*), sectoral (*KT*) and total profits (*K*), cross-country capital ownership (*KD* and K_q), wages (*L*), and transfers (*TRANSFERS*). Furthermore, the funds received by the government can be used to derive effective collection rates for tariffs (*tm*), sales tax (*tx*), value-added tax (*tva*), and capital (*tk*) and labor taxation (*tl*). It should be emphasized here that all tax rates in the model are effective net rates. This definition means, on the one hand, that taxes and subsidies to the same sector are netted out. On the other hand, the rates used here may deviate substantially from official rates, because the government (for one reason or the other) does not collect the amount of money that would follow from simply multiplying official rates with the quantities reported. This adjustment is particularly important in the case of tariffs, where, due to exemptions, the effective collection rates are often substantially below the official tariff rates.

Special Issue: Automotive USA

A special problem for the CGE model is that the SAM reports a loss for the United States automotive sector in 1988. The standard methodology that equalizes capital endowment with profits would produce the meaningless result that the capital endowment in the sector is negative. In its place, we have taken the average profit rate in the sector for the next 5 years (1989-1993), which is 5.7 percent of turnover. This value for profitability has been multiplied by the sectoral turnover. The difference is carried along in the model in form of a constant.

Government consumption

A sectoral disaggregation of the government consumption (i.e., of those government revenues that are not used for transfers) is not available from the SAM. They had to be taken from another source. The sectoral breakdown of government consumption shares is taken from Ballard *et al.*(1985) and applied the 26 sectors of the SAM. These values are listed in Table 4-1. Since a similar sectoral breakdown was difficult to obtain for Mexico and Canada, the same government consumption shares were used for these countries.

Table 4-1. Disaggregation of government consumption shares

Sector	Percent of Government Consumption	Sector	Percent of Government Consumption
Agriculture	0.36	Iron and Steel	0.01
Mining	0.10	Non-Ferrous Metals	0.01
Petroleum	3.63	Wood & Metals	0.64
Food Processing	1.26	Non-Electr. Machines	2.30
Beverages	0.25	Electrical Machines	6.33
Tobacco	0.14	Transport Equipment	13.45
Textiles	0.09	Other Manufactures	2.42
Wearing Apparel	0.39	Construction	27.96
Leather	0.08	Electricity	4.18
Paper	2.76	Commerce	3.04
Chemicals	2.10	Transport & Commun.	4.89
Rubber	0.73	Finance & Insurance	1.97
Non-Metal Minerals	0.05	Other Services	20.85

4.1.2. Asymmetric Structure of NAFTA

The United States' economy clearly dominates the North American Free Trade Agreement. In 1988 the U.S. economy had a GDP of 4504 bn U.S. dollar. Those of Canada and Mexico were 438 and 163 bn U.S. dollars, respectively. These figures mean that the GDP of the USA makes up over 88 percent of the total NAFTA economies, while that of Canada is 8.6 percent. Mexico's economy is only 3.2 percent of the total NAFTA economy.

The U.S. also dominates the trade of the area. Between 50 and 60 percent of Canadian and Mexican exports and imports are directed at the United States. By contrast, these two countries combined absorb only 20 percent of the U.S. trade. Table 4-2 shows that trade between Mexico and Canada is small. These figures even underestimate the one-sidedness of the trade dependency, because barely 5 percent of the U.S. production is exported. This share is much higher for the other two countries, with 12 percent for Mexico, respectively 15 percent for Canada. Unsurprisingly, therefore NAFTA will affect the USA less than the other two countries in relative, though not in absolute terms.

Table 4-2: Trade in billion U.S. dollars (1988)

	Importers			
Exporters	**USA**	**Mexico**	**Canada**	**World**
USA	**-**	**16.840**	**69.802**	**340.262**
Mexico	**19.730**	**-**	**1.078**	**15.053**
Canada	**79.172**	**0.397**	**-**	**49.359**
World	**434.741**	**14.668**	**54.350**	**-**

4.1.3. Differences in Economic Development of NAFTA States

Income Gap

Mexico's economic development lags substantially behind that of the two northern members of NAFTA. In the base year 1988, Mexico's per capita income is a mere $2,000, while that of the Canada and the USA are $16,500 and $18,000, respectively. However, Mexico looks more prosperous, when GDP is calculated based on purchasing power parity. Summers and Heston (1991) list 1988 per capita GDP of $19,851 (USA), $17,681 (Canada), and $5,323 (Mexico).

The income distribution is Mexico is more unequal than in the other two countries. The wealthiest 10 % of the population in Mexico control about 40 % of the income, while the equivalent figure for Canada and the U.S. is 25%. The aspect of income inequality is certainly important in explaining the political mechanism of regulation setting. However, influence of income inequality on the simulation results cannot be analyzed with the ETERNA modeling tool, which employs the assumption of a representative consumer.

Structure of the Economy

Naturally, the different levels of development are also reflected in the economic structure of the countries. Tables 3a-c break down the three North American economies into 26 sectors.[20]

Compared to the developed NAFTA countries, Mexico has a fairly high share of primary sectors. The combined share of agriculture, mining, and petroleum production is nearly 18 percent of its output, while their values for the USA and Canada are only 5, respectively 8 percent. By contrast, the northern countries have a more developed tertiary sector. Transport, commerce, financial, insurance, and other services combine to about a third of the U.S. and Canadian economies. Their importance for Mexico is less than one fourth. These facts roughly match the standard patterns observed in developed and developing nations.

However, the interpretation of the statistical information therefore requires some caution. First, every sector is an aggregation of firms of various sizes and trades. These are treated as homogeneous although they do not necessarily react the same way to economic policies. Second, and more problematic may be the application of the same sectoral definition across countries with a different state of development, such as Mexico on the one hand, and Canada and the USA on the other. This definition will be discussed in more detail for the calculation of emissions factors in Section 4.2.

The greater dependence on exports of Canada and Mexico than for the U.S. was already mentioned. Sectoral figures for the U.S. export shares never exceed 20 percent while in the other two countries, up to 70 percent of a sector can go to foreign markets, mainly the USA. One can distinguish to some extent the influence of natural endowments on the national economy and consequently their exports. For instance, sparsely populated Canada is more intensive than the USA in the production of primary goods. More extreme is the situation in Mexico. Petroleum constitutes over 40 percent of Mexico's exports. This trade gives this sector a level in importance that is well in excess of what its share in total GDP would suggest. The dependency on a single product group is another characteristic that Mexico has in common with many developing countries.

However, even before the implementation of the NAFTA treaty, Mexico was moving to a more diversified export base. In particular, the large export and import figures for transport equipment and machinery hint at the great importance of the *maquiladora* industry. *Maquiladoras* are export-processing zones located along the Mexican side of the US-Mexican border. In these zones, companies enjoy exemptions from duties on imports into Mexico when they re-export the products back to the United States (Hufbauer and Schott 1992). However, the relative importance of the special zones is likely to decrease, because the NAFTA treaty reduces tariffs for all of Mexico.

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[20] Government services are not listed separately, but are integrated into the sectors.

Table 4-3a: Key sectoral data for the United States

Sector	Production (%)	Value Added (%)	Demand (%)	Exports (%)	Imports (%)	Export share (%)	Import share (%)
Agriculture	2.4	2.0	2.2	5.1	1.4	10.6	4.2
Mining	0.3	0.4	0.3	1.2	0.4	19.6	10.2
Petroleum	2.4	1.8	2.8	2.5	8.0	5.2	18.3
Food Processing	3.5	1.6	3.4	3.0	2.3	4.2	4.2
Beverages	0.6	0.2	0.6	0.1	0.7	1.1	7.2
Tobacco	0.4	0.3	0.4	0.7	0.1	9.0	2.4
Textiles	1.0	0.7	1.0	0.8	1.3	3.9	7.6
Wearing Apparel	0.7	0.4	1.0	0.3	5.0	1.9	30.9
Leather	0.1	0.1	0.2	0.1	2.1	6.8	58.6
Paper	2.5	1.8	2.5	2.8	2.5	5.7	6.4
Chemicals	2.4	1.5	2.2	7.7	3.4	16.2	10.0
Rubber	1.5	1.0	1.4	4.4	2.3	15.0	10.7
Non-Metal Minerals	0.8	0.7	0.8	0.6	1.3	3.7	10.1
Iron and Steel	0.9	0.4	0.9	3.2	2.5	18.5	18.5
Non-Ferrous Metals	0.8	0.4	0.9	0.6	1.8	3.8	12.8
Wood & Metals	3.2	2.5	3.2	3.4	4.3	5.4	8.4
Non-Electr. Machines	1.9	1.3	1.9	6.3	6.0	16.8	19.9
Electrical Machines	3.4	2.7	3.8	10.3	15.0	15.0	24.8
Transport Equipment	3.7	2.4	4.0	16.1	17.2	21.6	27.5
Other Manufactures	1.1	0.9	1.3	2.3	6.2	10.7	29.1
Construction	7.0	5.1	6.9	0.0	0.0	0.0	0.0
Electricity	3.3	3.5	3.8	0.1	8.5	0.2	14.0
Commerce	11.7	12.7	11.0	10.0	0.0	4.3	0.0
Transport & Commun.	4.8	5.9	4.8	5.9	5.1	6.1	6.8
Finance & Insurance	14.3	16.3	14.0	5.8	2.1	2.0	1.0
Other Services	25.3	33.5	24.7	6.4	0.4	1.3	0.1
Total	100.0	100.0	100.0	100.0	100.0	5.0	6.3

Table 4-3b: Key Sectoral Data for Mexico

Sectors	Production (%)	Value Added (%)	Demand (%)	Exports (%)	Imports (%)	Export share (%)	Import share (%)
Agriculture	7.9	7.9	8.5	3.7	8.4	5.8	11.5
Mining	1.4	1.6	1.1	3.1	1.5	29.1	14.8
Petroleum	8.3	3.4	3.4	41.5	2.5	63.2	8.8
Food Processing	8.8	5.6	9.1	3.1	5.7	4.4	7.3
Beverages	1.6	1.0	1.6	0.9	0.5	7.3	3.3
Tobacco	0.3	0.1	0.3	0.1	0.0	4.8	0.1
Textiles	1.5	1.2	1.5	0.9	1.5	7.9	11.2
Wearing Apparel	1.3	0.8	1.2	1.6	1.2	15.7	11.3
Leather	0.8	0.7	0.8	0.7	0.7	10.0	9.4
Paper	1.8	1.6	2.1	1.4	4.3	9.9	23.9
Chemicals	3.6	2.4	4.0	4.9	9.1	17.6	26.3
Rubber	1.0	0.8	1.3	1.3	4.2	16.2	36.5
Non-Metal Minerals	1.6	1.9	1.6	0.3	0.7	2.7	5.4
Iron and Steel	1.4	1.1	2.2	1.3	8.0	11.6	42.4
Non-Ferrous Metals	0.8	0.7	0.7	2.2	1.7	36.5	29.2
Wood & Metals	2.5	1.3	2.5	3.7	4.6	19.3	21.0
Non-Electr. Machines	0.9	1.0	2.6	2.9	17.7	39.5	78.2
Electrical Machines	1.8	1.4	1.4	10.1	7.9	71.5	64.2
Transport Equipment	3.3	2.6	3.6	12.9	16.9	50.2	54.7
Other Manufactures	0.9	0.6	0.8	3.3	3.0	47.6	42.7
Construction	6.7	3.9	6.7	0.0	0.0	0.0	0.0
Electricity	1.2	1.4	1.2	0.0	0.0	0.0	0.0
Commerce	17.4	26.6	17.6	0.0	0.0	0.0	0.0
Transp. &Commun.	6.1	7.7	6.2	0.0	0.0	0.0	0.0
Finance & Insurance	5.8	7.8	5.9	0.0	0.0	0.0	0.0
Other Services	11.6	15.1	11.7	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	12.7	11.6

Table 4-3c: Key Sectoral Data for the Canada

Sector	Production (%)	Value Added (%)	Demand (%)	Exports (%)	Imports (%)	Export share (%)	Import share (%)
Agriculture	3.6	3.4	3.1	5.0	1.4	20.8	7.1
Mining	1.5	2.7	1.5	2.5	2.6	25.7	26.2
Petroleum	3.3	2.0	2.7	7.0	3.1	31.6	16.8
Food Processing	4.1	2.4	4.1	2.3	2.8	8.6	10.2
Beverages	0.7	0.6	0.7	0.4	0.6	8.8	12.7
Tobacco	0.2	0.2	0.2	0.1	0.0	4.3	1.6
Textiles	0.7	0.6	0.9	0.7	2.1	16.2	36.2
Wearing Apparel	0.8	0.7	1.1	0.4	2.0	6.7	27.8
Leather	0.2	0.1	0.3	0.1	1.0	12.8	53.4
Paper	4.1	3.8	2.7	11.7	2.4	42.6	13.3
Chemicals	1.9	1.9	2.6	0.7	4.9	5.2	28.3
Rubber	0.8	0.8	0.9	1.3	2.0	22.6	31.1
Non-Metal Minerals	0.8	0.8	0.9	0.9	1.2	15.8	21.5
Iron and Steel	1.2	1.0	1.3	1.5	1.7	18.6	20.0
Non-Ferrous Metals	1.0	1.0	0.9	2.8	1.8	40.4	30.8
Wood & Metals	3.9	3.4	3.5	7.5	4.5	28.3	19.3
Non-Electr. Machines	1.8	1.0	2.7	5.8	12.0	49.4	66.9
Electrical Machines	2.0	1.7	2.5	4.1	7.9	31.1	46.8
Transport Equipment	6.7	3.1	5.9	30.3	24.9	67.8	63.4
Other Manufactures	1.0	0.7	1.3	2.2	4.6	34.2	52.0
Construction	10.5	8.6	10.5	0.0	0.0	0.0	0.0
Electricity	2.2	3.6	2.1	0.5	0.1	3.7	0.6
Commerce	12.8	17.9	12.5	3.2	0.9	3.7	1.0
Transp. & Commun.	7.6	8.0	7.1	5.6	2.2	10.9	4.6
Finance & Insurance	8.4	10.2	9.1	0.8	5.4	1.5	9.0
Other Services	18.2	19.8	19.0	2.7	7.8	2.2	6.1
Total	100.0	100.0	100.0	100.0	100.0	15.0	15.0

Labor intensity

Table 4-4 shows the capital to labor ratios of the various sectors. The values are calculated from the factor rewards, where capital is defined as the sum of profits and interest payments, and labor denotes the gross wage bill. It is remarkable that the ratio of capital to labor inputs in the economy is five times higher for Mexico than for the USA and Canada (first three columns of the Table 4-4). This value appears to be in stark contrast to the common perception of Mexico as being labor-abundant and the USA and Canada as being capital abundant. However, the capital-labor ratios reflect degrees of efficiency in the two economies. The capital-labor ratio in the U.S. is lower than that of Mexico because American wages are higher than Mexican wages reflecting higher U.S. labor productivity. Considering this aspect of labor efficiency, the United States and Canada end up being actually more labor-abundant than Mexico, although one unit of production requires a larger number of hours worked in Mexico than in the other two countries.

Barring large differences in the elasticity of substitution between labor and capital, one would expect that across countries the capital-labor ratios of the individual sectors would vary more or less in parallel. To analyze this aspect, the last three columns of the table present the ratios of the first three columns normalized by dividing them by the average capital-labor ratio. Clearly, the difference between Mexico and the other two states is decreased. Even so, the U.S. and Canada remain more similar in the relative labor-capital abundance of their input structure than Mexico with either of the two.

A part of the variation in the labor-capital intensities is likely to be a statistical artifact. Among countries there are differences in the composition of production within the individual sectors is likely to vary systematically among countries. Furthermore, the statistical definition of the sectors might be artificially influenced by the industrial organization of a sector. If a company out-sources part of its activities, they will be registered as production of the sector in which the supplier is categorized. Another explanation lies in actual technological differences. These will be more prevalent between Mexico and the other two countries than between Canada and the US. Furthermore, the interpretation of Mexico as labor-scarce is a simplification. Mexico is probably scarce in skilled workers, while there is no lack of unskilled labor. The productivity of unskilled labor is, however, highly dependent on the existence of a trained middle management to put them to their best use. The degree to which the lack of highly skilled labor affects productivity will be different across sectors. For instance, the production of electricity is likely to have little use of unskilled workers, which would explain that their production structure is nearly the same everywhere. By contrast, in the sectors where one would most likely suspect sweatshop conditions, the differences in labor intensity are the highest, e.g. for textiles, apparel and leather, and also in food processing and certain manufacturing sectors. It is these sectoral differences in input intensities across countries that are important in explaining why sectors react differently to changes in the trade regime.

Table 4-4

Sector
Agricultur
Mining
Petroleum
Food Proc
Beverages
Tobacco
Textiles
Wearing A
Leather
Paper
Chemicals
Rubber
Non-Meta
Iron and S
Non-Ferro
Wood & I
Non-Elec
Electrical
Transport
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Commerc
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Table 4-4. Sectoral capital-labor ratios

Sector	Ratio of Capital to Labor shares (absolute values)			Ratio of Capital to Labor shares (Country averages = 1)		
	USA	Mexico	Canada	USA	Mexico	Canada
Agriculture	1.4	4.1	1.5	2.3	1.3	2.4
Mining	0.4	2.1	0.9	0.7	0.7	1.4
Petroleum	2.8	7.6	1.3	4.6	2.5	2.1
Food Processing	0.6	5.0	0.5	1.0	1.6	0.7
Beverages	0.5	3.1	0.7	0.9	1.0	1.1
Tobacco	1.9	3.0	1.2	3.1	1.0	1.9
Textiles	0.3	2.2	0.3	0.4	0.7	0.5
Wearing Apparel	0.2	2.7	0.2	0.4	0.9	0.3
Leather	0.6	1.8	0.1	0.9	0.6	0.2
Paper	0.4	3.4	0.5	0.6	1.1	0.7
Chemicals	0.7	3.3	0.8	1.2	1.0	1.3
Rubber	0.3	2.5	0.2	0.5	0.8	0.3
Non-Metal Minerals	0.3	3.7	0.5	0.4	1.2	0.8
Iron and Steel	0.1	2.5	0.3	0.1	0.8	0.4
Non-Ferrous Metals	0.2	3.4	0.7	0.3	1.1	1.0
Wood & Metals	0.2	2.8	0.2	0.3	0.9	0.3
Non-Electr. Machines	0.2	2.3	0.3	0.4	0.7	0.5
Electrical Machines	0.2	1.9	0.3	0.4	0.6	0.5
Transport Equipment	0.1	2.3	0.3	0.2	0.7	0.4
Other Manufactures	0.5	4.1	0.2	0.8	1.3	0.4
Construction	0.1	0.5	0.2	0.2	0.2	0.4
Electricity	1.8	1.9	2.0	3.1	0.6	3.1
Commerce	0.3	4.0	0.2	0.5	1.3	0.4
Transp. & Commun.	0.4	2.4	0.4	0.7	0.8	0.7
Finance & Insurance	1.8	3.3	0.5	3.0	1.0	0.8
Other Services	0.2	0.8	1.1	0.4	0.3	1.8
AVERAGE	0.6	3.1	0.6	1.0	1.0	1.0

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Tax Structure

Mexico is also set apart by the structure of its taxes. Table 4-5 lists the composition of the taxes in a simplified structure that is also adopted in the general equilibrium model. For instance, government subsidies to enterprises are netted out; property taxes and taxes on businesses are treated as taxes on capital; taxes on households are allocated to taxes on labor and capital; government transfers reduce the labor taxes; sales and "sin" taxes are listed as indirect taxes. Nevertheless, the stylized structure of the tax is in some aspects quite revealing.

First, the effective tax collection of Mexico is only half of that of Canada and the United States. However, this tax collection rate does not necessarily mean that the Mexican government has a comparatively lesser influence on its economy than the other countries. For, instance the government still controls PEMEX, the petrol monopoly, which has such an overwhelming importance on Mexico's exports and, hence, the overall economy (Hufbauer and Schott 1992). However, this control does not show in the tax statistics.

Second, while the most important taxes are labor-related for the United States and Canada, this share is rather small for Mexico. Instead, the country relies primarily on indirect taxation and value added taxation. It is likely that these shares are simply the result of greater ease in collecting them, rather than a strategic choice on part of the Mexican government.

Table 4-5.

Taxes
Labor tax
Capital ta
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Value add
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Table 4-5. Structure of tax collection in the NAFTA countries

	USA		Mexico		Canada	
Taxes	bn $	% of taxes	bn $	% of taxes	bn $	% of taxes
Labor tax	800	51.2	5	19.0	64	41.8
Capital tax	369	23.6	7	25.1	35	23.3
Indirect tax	376	24.1	9	31.9	49	32.2
Value added tax	0	0.0	6	21.3	0	0.0
Duties	16	1.1	1	2.9	4	2.4
Effective tax collection	1562	34.7% of GDP	28	17.2% of GDP	153	34.8% of GDP

Note: Figures are net of subsidies and consolidated, e.g., excises are integrated into indirect taxes, etc.

4.1.4. Trade Protection before NAFTA

Tariff rates

The effect of the trade liberalization implied by NAFTA depends crucially on the pre-existing trade barrier. Table 4-6 lists the tariff levels (variable *tm* of the model) of the three NAFTA members applied in 1988. The numbers in the table do not report official tariff rates but effective collection tariff rates. Mathematically this is the value of customs revenues divided by the value of imports. There are some marked differences among the sectors. Tariff collection rates are high for textile and apparel imports in Canada and the US, but for other sectors no simple system emerges that explains the various levels of tariff collection. Overall, the effective tariff collection in all three countries is surprisingly low, being on average between 1 and 5 percent among the three NAFTA partners. Reasons are, first, that large amounts of imports that are not covered by tariffs, for instance the *maquiladora* industry. Second, the collection rates are likely to under-report the actual protection these tariffs exert: the average rate is not identical with the marginal tariff rate. In the extreme case, a tariff may be so high that it is prohibitive for any trade. This extreme would result in an effective tariff collection of zero, which might give the false impression that there is no trade barrier at all.

Table 4-

Agricultur
Mining
Petroleum
Food Proc
Beverages
Tobacco
Textiles
Wearing A
Leather
Paper
Chemicals
Rubber
Non-Meta
Iron and S
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Table 4-6: Effective Tariff Collection of North America (in percent of import value)

	USA			Mexico			Canada		
	ROW	Canada	Mexico	ROW	USA	Canada	ROW	USA	Mexico
Agriculture	1	2	6	0	1	0	1	1	2
Mining	0	0	1	0	2	0	0	0	0
Petroleum	1	0	0	1	4	0	0	0	0
Food Processing	4	2	6	1	3	2	4	4	5
Beverages	3	3	2	0	0	0	35	35	35
Tobacco	10	17	8	0	0	0	8	8	0
Textiles	10	6	7	3	2	0	12	12	12
Wearing Apparel	19	9	16	5	2	0	18	18	20
Leather	9	22	5	0	1	0	13	13	0
Paper	1	0	2	2	2	3	4	4	0
Chemicals	5	17	2	2	3	0	5	5	8
Rubber	6	10	4	4	1	0	7	7	0
Non-Metal Minerals	6	1	0	4	8	0	5	5	8
Iron and Steel	4	3	3	1	4	0	4	4	5
Non-Ferrous Metals	1	1	0	2	4	0	2	2	0
Wood & Metals	4	1	2	4	3	0	6	6	6
Non-Electr. Mach.	3	1	1	5	3	5	2	2	2
Electrical Machines	3	2	3	7	1	5	4	4	4
Transport Equip.	3	0	2	1	2	1	7	0	7
Other Manufactures	4	1	3	2	10	0	4	4	5
All	5	1	3	3	2	2	7	3	5

Non-tariff barriers

Roland-Holst *et al.* (1994) provide important supplementary information on non-tariff barriers, such as quotas, voluntary export restraints, rules of origin, and burdensome paperwork. This effective trade protection is translated into an *ad valorem* tariff equivalent (Table 4-7). The authors calculated the figures from a composite of three sources: the observed sectoral tariff collection rates in the SAM; independent sectoral estimates by other researchers; and the combined UNCTAD-GATT database of four-digit SITC trade control measures. In the model, non-tariff barriers (*tn*), are calculated simply as the differences between the tariffs and the value of the table. A multiplication of the figures with actual imports allows the calculation of the loss through rent seeking (*IMPORT LOSS*).

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Non-tariff barriers in North America were quite substantial in 1988. They were particularly high against Canadian exports. Both Mexico and the United States tend to be more protectionist against Canada than against the rest of the world or each other. The United States had the highest average import barriers against its neighbors, and Canada maintained the lowest. Mexico and the USA were highly protectionist in primary exports.[21] Mexico and Canada focus most of their protection on agricultural imports. There is also a certain complementarity at work. Where barriers are high in the two northern countries (e.g., textiles, apparel, and leather), they are low in Mexico. Conversely, Mexico applies high trade barriers, where it is not competitive (e.g., paper). Here the other two countries apply low protection rates.

[21] There are, however a number of zeros for Mexican barriers against Canada. However, this may be either a statistical artifact either because low trade volumes that do not allow for better estimates, or that the Mexican government did not need to bother to impede the already small trade flows between the two countries.

Table 4-7

Agricultur
Mining
Petroleum
Food Proc
Beverages
Tobacco
Textiles
Wearing
Leather
Paper
Chemical
Rubber
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Table 4-7: Ad valorem estimates for North American import protection (tariff and non-tariff barriers in percent of pre-tariff import value)

	USA			Mexico			Canada		
	ROW	Can.	Mex.	ROW	USA	Can.	ROW	USA	Mex.o
Agriculture	24	14	42	84	84	100	81	83	99
Mining	4	6	37	0	2	0	1	0	0
Petroleum	92	65	98	86	89	0	25	48	7
Food Processing	27	23	22	95	101	82	58	58	78
Beverages	97	97	92	100	100	0	35	35	35
Tobacco	21	81	23	100	100	0	8	8	0
Textiles	51	6	85	3	2	0	85	79	103
Wearing Apparel	19	9	16	5	2	0	18	18	20
Leather	9	22	5	2	3	0	105	103	39
Paper	1	0	2	64	66	87	5	4	0
Chemicals	7	18	9	9	7	9	14	12	8
Rubber	11	17	5	4	1	0	9	9	0
Non-Metal Mineral	9	1	57	7	11	0	19	14	11
Iron and Steel	83	48	75	47	43	0	86	74	95
Non-Ferrous Metal	2	1	0	2	4	0	2	2	0
Wood & Metals	13	5	10	4	3	0	16	14	9
Non-Electr. Machin	11	2	1	7	4	5	3	2	2
Electrical Machines	13	7	3	13	8	15	5	6	4
Transport Equipme	71	65	6	13	19	1	68	57	83
Other Manufactures	28	3	24	3	11	0	30	17	17
Economy-wide	28	38	10	25	15	26	36	31	32

Source: Roland-Holst, Reinert and Shiells 1994

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4.1.5. Elasticities

The responsiveness of an economy to policy changes depends on various economic elasticities. Table 4-8 lists the most important elasticities. They are taken from Roland-Holst et al. (1994). The labor-capital elasticity of substitution (σ), the Armington elasticities (δ), and the demand elasticity of the rest of the world (ν) are defined according to standard conventions. The figures for elasticity of scale (*scale*) imply that an increase in inputs by X % increases output by $(1+X\%)^{1+scale}-1$.

In addition, the uncompensated wage elasticity of labor supply is assumed to lie at a value of 0.10, the compensated value is at 0.15. This is the value derived by Burtless (1987). The leisure endowment and the leisure-consumption elasticity of substitution (τ) in the top nest of the utility function are calibrated to reproduce these values. Furthermore, the elasticity of substitution for private demand (ρ) is set to a value 1.5. The equivalent value for government demand (ϑ) is set to be equal to one. This value translates into own price elasticities between 1.4 and 1.5.[22]

[22] In a CES function, uncompensated price elasticity equals $-\sigma - (1-\sigma)\,\alpha$, where σ is the substitution elasticity, and α is the consumption share of a sector. Since values for α are low due to high disaggregation, the price elasticities remain close to σ, which is set at 1.5.

Table 4-8

Sector
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Mining
Petroleum
Food Process
Beverages
Tobacco
Textiles
Wearing Ap
Leather
Paper
Chemicals
Rubber
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Non-Electr.
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Construction
Electricity
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Other Servi

Source: R

Table 4-8: Various elasticities by sector for all regions

	Elasticity of Scale (in %)			Labor-Capital Elasticity of Substitution			Armington Elasticities			Demand Elast.
Sector	USA	Mex	Can	USA	Mexico	Canada	USA	Mexico	Canada	ROW
Agriculture	0	0	0	0.680	0.768	0.680	1.500	1.500	2.250	4
Mining	5	5	5	0.900	0.950	0.900	1.062	1.062	0.781	5
Petroleum	10	10	8	0.861	0.861	0.861	0.660	0.660	0.580	20
Food Processing	18	18	12	0.710	1.100	0.710	0.889	0.889	1.007	4
Beverages	13	13	18	0.710	1.100	0.710	0.326	0.326	0.726	3
Tobacco	7	7	24	0.708	1.100	0.708	1.008	1.008	1.008	3
Textiles	9	9	14	0.900	1.100	0.900	0.918	0.918	1.022	3
Wearing Apparel	6	6	13	0.900	1.100	0.900	0.479	0.479	0.802	3
Leather	2	2	14	0.900	1.100	0.900	1.007	1.007	1.066	3
Paper	16	16	22	0.900	1.100	0.900	0.967	0.967	0.734	3
Chemicals	12	12	19	0.960	1.100	0.960	0.903	0.903	0.702	3
Rubber	13	13	18	0.960	1.100	0.960	1.026	1.026	0.763	3
Non-Metal Minera	25	25	16	0.901	1.100	0.901	1.152	1.152	0.826	3
Iron and Steel	14	14	13	0.740	1.100	0.740	0.931	0.931	0.716	3
Non-Ferrous Met.	14	14	20	0.740	1.100	0.740	0.825	0.825	0.663	3
Wood & Metals	9	9	14	0.811	0.811	0.811	0.888	0.888	0.594	3
Non-Electr. Mach.	8	8	9	0.740	0.740	0.740	1.012	1.012	0.694	3
Electrical Machin.	8	8	28	0.740	0.740	0.740	1.035	1.035	0.705	3
Transp. Equip.	10	10	27	0.867	0.867	0.867	0.982	0.982	0.679	3
Other Manufacture	9	9	12	0.740	0.740	0.740	0.550	0.550	0.463	3
Construction	0	0	0	0.900	0.500	0.900	1.500	1.500	1.200	3
Electricity	0	0	0	0.521	0.300	0.521	1.200	1.500	1.300	0.5
Commerce	0	0	0	0.800	0.300	0.800	1.500	1.300	1.200	3
Trans.& Comm.	0	0	0	0.502	0.300	0.502	1.100	1.200	1.400	3
Finance & Insur.	0	0	0	0.800	0.800	0.800	1.500	1.200	1.100	3
Other Services	0	0	0	0.800	0.800	0.800	1.300	1.100	1.200	3

Source: Roland-Holst, Reinert, and Shiells (1994, p.67); last column adapted from GREEN (Burniaux et al. 1992).

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4.2. Environmental Components

The integration of an environmental component into economic modeling needs to take place both on the production side as well as on the side of the environmental externality. To accomplish such integration, ideally three (quantitative) information components should be available. First, emissions of each sector need to be known. This information allows the evaluation of sectoral changes on emission levels. Second, an abatement function is needed. This is crucial for evaluating the impact of regulations on the cost structure of various sectors. Third, the emissions externalities should be included. In its simplest form, an externality constitutes a pure welfare reduction. In this case, the externality does not affect the production or consumption patterns of the economy and remains external to the economic model itself. By contrast, if emissions affect certain production or consumption factors, this impact needs to be internalized into the model. Unfortunately, the data situation is not such that the relationships of the environmental component can be easily constructed. Ten steps are necessary for establishing the full economy-environment relationship for the North American Free Trade area. These steps follow a combination of logical and practical reasons, especially limited data availability.

(1) Derivation of the sectoral emission coefficients (available only for the U.S.).

(2) Derivation of sectoral abatement costs (available only for the U.S.).

(3) Construction of the abatement function.

(4) Extrapolation of U.S. relationships to those of the other two NAFTA countries.

(5) Calculation of total emissions for each country.

(6) Association of emission values with ambient pollution levels.

(7) Establishing the effect of pollution on human health.

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(8) Calculation of the degree to which health limits labor as a production factor.

(9) Quantification of total welfare effect.

(10) Political income elasticity of pollution abatement.

In the following sections each of these eight individual steps will be addressed in turn. In addition, one could list the choice of the pollutant(s) included in the analysis as an important criterion. It will become clear that a whole set of uncertainties is involved in constructing the environmental data. These uncertainties stress the experimental nature of this paper.

4.2.1. Sectoral Emission Coefficients in the United States

The first task involves taking stock of the sectoral information that exists for the United States. Sectoral emission values draw heavily on the work undertaken within the framework of the World Bank's Industrial Pollution Projection System (IPPS; see Hettige *et al. 1995*). This work, in turn, is indebted to the Toxic Release Inventory of the U.S. Environmental Protection Agency. The IPPS lists various air, land and water pollution emissions for industrial sectors at the three-digit level. The main interest of this paper is in air pollutants, because they have fairly well researched damage functions. Air pollution tends to spread over large areas, and protection from its hazardous effects is difficult and costly. By contrast, land and water pollutants are generally of a local nature. This concentration means also that damages caused by pollution of these two media cannot be generalized because they are highly location dependent and can often be avoided or abated. In the extreme, a polluted area could simply be roped off.

Major air pollutants included in the IPPS are SO_2, NO_2, CO, total particulate matter (TP), particles smaller than 10 microns (PM10), and volatile organic compounds (VOC). Table 4-9 lists the toxic release coefficients as a function of sectoral value added. Data are adjusted to match t

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match the disaggregation into 26 sectors used so far. Since the IPPS database only contains data on manufacturing sectors, it is necessary to construct data for the other sectors. The following adjustments are made: Emissions for agriculture are set to zero. Mining is assumed to have half the emission intensity of non-metal minerals. Construction is given equal values to those of the wood and metal sector. Emission values for commerce, finance and insurance, and other services are set equal to the lowest values assigned to any of the manufacturing sectors. For electricity production and transport, the values are calibrated such that they replicated OECD (1995) emission figures.[23] Because the United States constitutes the original data source for the constructing the IPPS data, the assumption that these values reflect sectoral emission averages for the United States is unproblematic.

[23] Values for electricity are calibrated to constitute for SO2 69% of total emissions; for NO2 22%; CO 5%; VOC 20%, and particles 20%. The analogous emission allocation for transport is for SO2 4%, for NO2 31%, for CO 80%, VOC 40 %, and for particles 25%. It is assumed that 40 percent of transport is commercial transport. Emissions for private transport and household emissions are not incorporated into these figures.

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Table 4-9: Pollution intensity of the production sectors (pounds per USD million value added)

Sector	SO_2	NO_2	CO	Volatile Organic Compounds (VOC)	Fine Particulates (PM10)	Total Suspended Particulates (TSP)	Toxicity Weighted Index
Agriculture	0	0	0	0	0	0	0
Mining	26259	177	3015	855	21555	17024	619
Petroleum	82270	48716	41302	32495	1441	16012	751
Food Processing	6115	4548	1653	1406	2328	5563	202
Beverages	3893	1881	212	7588	97	294	29
Tobacco	1840	1113	145	366	14	34	5
Textiles	1948	1637	495	3000	29	736	35
Wearing Apparel	1105	289	94	2602	31	370	18
Leather	1105	289	94	2602	31	370	18
Paper	13290	7801	15060	3018	740	2583	123
Chemicals	7443	8115	15628	7318	529	1535	94
Rubber	2412	831	104	3083	42	275	18
Non-Metal Minerals	52518	35517	6030	1711	43110	34049	1239
Iron and Steel	41044	17829	63961	5494	11344	9510	425
Non-Ferrous Metals	123489	4022	57444	4492	1135	10371	460
Wood & Metals	1199	1702	3454	4704	487	2303	92
Non-Electr. Mach.	1894	801	1876	1499	2	356	18
Electrical Machines	1158	551	684	815	5	122	8
Transport Equipment	3082	1301	410	6427	129	913	47
Other Manufactures	112	200	42	737	25	77	4
Construction	1199	1702	3454	4704	487	2303	92
Electricity	362087	34375	30440	31647	6929	14727	797
Commerce	112	200	42	366	3	34	2
Transp. & Comm..	6712	15490	155758	20241	2770	5887	377
Finance & Insurance	112	200	42	366	3	34	2
Other Services	112	200	42	366	3	34	2

Source: Adapted from IPPS, March 1995; Based on OECD figures (*Environmental Data 1995*). For the toxicity weight the shares are assumed to be 70 % for TSP, and 7.5 % for all other except PM10, which is set to zero to avoid double counting.

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The model will focus on TSP, as will be explained further below. Table 4-10 presents the cross correlation of various sectoral emission indicators to provide a simple test whether TSP constitutes a good approximation of a larger pollution problem: TSP, toxicity, PM10 and NO_2 form a close cluster. This close clustering is particularly true for the correlation of the logarithmic values, which assigns less weight to the extreme values. Within this group, the choice of an indicator is relatively easy. By contrast, the correlation of the first cluster with CO and VOC emission factors is relatively low. SO_2 takes an intermediate position. Chapter 5 will report to what degree the results depend on the choice of the pollutant.

Table 4-10: Correlation matrix of various sectoral emission parameters *(logarithmic in italics)*

	TSP	TOX	PM10	NO_2	SO_2	CO	VOC
TSP	1.000	0.982	0.890	0.832	0.474	0.233	0.346
TOX	*0.994*	1.000	0.809	0.896	0.594	0.348	0.504
PM10	*0.939*	*0.947*	1.000	0.574	0.194	0.044	-0.027
NO_2	*0.902*	*0.934*	*0.900*	1.000	0.596	0.373	0.746
SO_2	*0.877*	*0.910*	*0.824*	*0.906*	1.000	0.225	0.682
CO	*0.853*	*0.874*	*0.776*	*0.874*	*0.824*	1.000	0.534
VOC	*0.674*	*0.705*	*0.573*	*0.660*	*0.678*	*0.706*	1.000

4.2.2. Sectoral Abatement Costs in the United States

Information on abatement expenditures of manufacturing sectors in the U.S. is available from Low (1992) who compiled data of the U.S. Department of Commerce (1988a; 1988b). The first column of Table 4-11 lists sectoral abatement values. Similarly to the situation for emissions, values are set to zero for agriculture. For commerce, finance and insurance, and other services, values are assumed to be a third lower than those of the next lowest manufacturing sector, paper. They are set to 0.1 percent of production value. Following an estimate

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estimate by the European Commission (1994), abatement costs of electricity production zero are set to 9 percent of production costs.

The data result in relatively small costs of environmental abatement of only 0.6 percent of total production costs on average. Most manufacturing sectors face abatement costs of less than one third of one percent of production costs. The figures appear implausibly low and could hardly justify a discussion on the trade impact of environmental regulation. The data are certain to underestimate actual regulatory costs by one half.

First, even if it were possible to determine with precision the level of physical expenditures on environmental abatement, they would neglect the fact that the environmental drag on businesses includes a large number of intangible factors. These are resources spent dealing with administrative procedures, costs of government inspections, uncertainty and time losses in waiting for permits, risks of litigation, etc. For instance, Gray and Shadbegian (1993) estimate that, for every dollar that appears in a company's books on emission reduction, actual profits drop by roughly 3 to 4 dollars, with some variation among sectors.

Second, the data listed in the first column of the Table are only based on those expenditures that serve exclusively the purpose of pollution abatement. However, emissions control is increasingly integrated into production equipment and production processes. Therefore, it is difficult to separate statistically what is purely productive expenditure and what production component serves environmental purposes.

Table 4-11: Derivation of abatement expenditures for United States in 1988

Sector	U.S. Domestic production (bn USD)[a)]	abatement costs (% of production)[b)]	total abatement costs (bn USD)[c)]	adjusted abatement costs (% of production)[d)]	Adjusted total abatement costs[e)]
Agriculture	195.49	0.00	0.00	0.00	0.00
Mining	24.97	1.50	0.37	3.33	0.83
Petroleum	187.68	1.53	2.87	3.40	6.37
Food Processing	298.41	0.33	0.98	0.73	2.19
Beverages	49.45	0.33	0.16	0.73	0.36
Tobacco	31.06	0.16	0.05	0.36	0.11
Textiles	86.59	0.27	0.23	0.60	0.52
Wearing Apparel	62.58	0.27	0.17	0.60	0.38
Leather	8.55	0.24	0.02	0.53	0.05
Paper	210.67	0.14	0.29	0.31	0.65
Chemicals	199.16	1.18	2.35	2.62	5.22
Rubber	122.34	0.30	0.37	0.67	0.81
Non-Metal Mineral	64.92	0.70	0.45	1.55	1.01
Iron and Steel	73.67	1.21	0.89	2.69	1.98
Non-Ferrous Metal	69.92	0.48	0.34	1.07	0.75
Wood & Metals	268.40	0.32	0.86	0.71	1.91
Non-Electr. Mach.	157.25	0.18	0.28	0.40	0.63
Electrical Machines	291.74	0.35	1.02	0.78	2.27
Transport Equip.	312.24	0.28	0.87	0.62	1.94
Other Manufactures	91.91	0.22	0.20	0.49	0.45
Construction	594.58	0.30	1.78	0.67	3.96
Electricity	272.89	9.00	24.56	19.98	54.52
Commerce	869.94	0.10	0.87	0.22	1.93
Transp. & Comm.	391.82	1.48	5.80	3.29	12.88
Finance & Insur.	1114.47	0.10	1.11	0.22	2.47
Other Services	2143.40	0.10	2.14	0.22	4.76
TOTAL	8194.09	0.60	49.07	1.33	108.94

Source: a) Social accounting matrix of Reinert et al. (1992); b) Low (1992), Electric derived from European Commission (1994); costs for services are adapted from Rutledge and Vogan (1994): It is assumed that business abatement of mobile emissions can be attributed to transport and communications. Services, transport and communications, finance and insurance, and others are assumed to have abatement expenditures of 0.1 percent in raw expenditures, which is somewhat lower than the lowest manufacturing sector. c) = column a) times column b); d) and e) own calculations as described in text. See also Footnote 9.

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Environmental drag and the statistical underestimation justify that the raw figures provided by Low should be adjusted upwards. In particular, in light of the purpose of assessing the regulatory impact of differing regulations on trade determination, an uncritical acceptance of these data would prejudge the analytical outcome.

An ad hoc assessment of the order of magnitude to which environmental costs are embodied in production costs is possible by going back to original Department of Commerce data source that was used by Low and are summarized in the *Survey of Current Business* (Rutledge and Vogan 1994). Between 1975 and 1992, total annual pollution abatement in (constant 1987 dollars) increased from USD billion 57 to 87, denoting an increase of slightly over 50 percent. The data report an increase in capital expenditures by only 20 percent during the same time span.[24] This small increase reflects the statistical phenomenon of an increasing integration of pollution control into the equipment, which then can no longer be separated from productive investment.

Therefore, the reported data on current expenditure are likely to be a better approximation for the time trend of pollution abatement, because the technological integration of abatement affects them less. From 1975 until 1992, these figures increased from $17.1 billion to 38.7 billion, marking an increase by 126 percent.[25] If one applies this growth rate to capital expenditures in the 1975 (to net out statistical shrinkage) one yields an adjusted 1992 figure for total abatement expenditures of $ 131 billion instead of the $87 billion reported by

[24] The more relevant figure for our purposes would have been the depreciation of capital equipment to reflect the existing stock, rather than the figures for new investment.

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Rutledge and Vogan. For the base year of the NAFTA calculations 1988, the value is $109 billion. This figure represents 6.3 percent of the United States profits in that year, or 1.33 percent of GDP. The values for abatement expenditures that are reported by Low are therefore normalized to yield costs of that level (third column of Table 4-11).[26] In the model, these expenditures are assumed to burden only production factor capital and are used to calculate abatement capital (*KA*).[27] They are unlikely to overestimate the gross costs imposed on businesses.[28]

In addition, the figures leave out the significant share of abatement costs that accrue to households and government directly. This omission needs to be borne in mind when interpreting the simulation results. However, the trade incidence of private and public abatement costs would be less pronounced than those of producer abatement costs. Only those costs that are linked directly to the production process will substantially affect the location of industries. This impact on sectoral competitiveness does not exist if abatement costs are borne by other economic actors. However, evidently the financial externality affects the overall

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[25] Expenditures on motor vehicle emission abatement are subtracted, because of an interruption of the series.

[26] The values by Low (1992) present only pollution abatement operating costs, which excludes investment. Therefore, the adjustments in the table are higher than the calculation would suggest. Raw expenditures data are adjusted to yield total expenditures of 109 billion, i.e., multiplied by 2.22. This figure excludes about 1/3 of emission abatement, because it occurs within private consumption, i.e., private transport, heating, etc.

[27] In economic terms, this exclusive burdening of capital takes place, even if the abatement itself uses only labor as an input. In this case, the associated wage costs reduce the factor reward of capital. Conceptually, it does not matter whether we imagine the process as one of a reduced rate of return for a constant capital stock, or as one of a constant rate of return for a reduced capital stock.

[28] However, they overestimate the net costs, i.e. when the benefit of reduced externalities is considered.

economy: Costs that are borne by the consumers of certain products will affect consumption patterns. Pollution abatement undertaken by the government also affects the competitiveness of firms indirectly via an increased tax burden to finance the expenditure.

4.2.3. Abatement Functions

Information on abatement expenditure and the amount of emissions in each sector does not establish a relationship between the two parameters. The construction of an abatement function deals with two difficulties. First, little systematic information is available that could be used to construct sectoral abatement functions. Estimations by Hartman *et al.* (1997) are statistically not robust enough to be a base for sectorally differentiated abatement functions. Since the expenditure data do not allow a sectoral differentiation of the abatement cost function it must be assumed that a macroeconomically established relationship holds for each individual sector.

Second, it is not evident which part of the abatement costs should be attributed to which pollutant, because cleaner technology often reduces emissions for multiple pollutants. For instance, a technology that reduces fuel consumption reduces CO_2 emissions as well as emissions in particles, sulfur oxides, etc. Therefore a large component of joint costs make it practical to look at abatement costs and emissions in their entirety. A practical approach is to use a pollution index to reflect the cumulative benefits of all abatement efforts. The model uses two different indices. One is to only trace the development in particles, which already includes a variety of molecules, so that it correlates fairly well with other air pollutants. In addition, the impact of particles on health is statistically well established. For a sensitivity analysis, a pollution index based on toxicity weights will be used.

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In light of the poor data quality, this paper applies a simple approach for the construction of an abatement function based on aggregate emissions and abatement figures. To this end, U.S. time-series data on abatement expenditure from 1975 to 1992[29] are set into relation with air emission data during the same period (OECD 1989, and 1995-Environmental Data). Emissions of particulates (PM10) for all sources in the United States sank by one third for the reporting period from 1975 until 1992 (Table 4-12). Emissions of other pollutants sank during the same time by similar orders of magnitude, although there is some variation in the trend across pollutants. CO and SO_X and VOC emissions decrease by 17 to 36 percent during the period. However, NO_X emissions actually increase during this time period, in parallel with CO_2 emissions.

Table 4-12: Pollution abatement expenditures and air emissions in the United States

	1975	1992	Change (%)
Abatement expenditures a)	$58.1 bn	$131.6 bn	126.18
CO_2-Emissions (Mt) b)	4800	5035	4.90
PM10 (1000 tons) b)	10600	7080	-33.21
CO (1000 tons) b)	124731	79092	-36.59
NO_X (1000 tons) b)	20100	21001	4.48
SO_X (1000 tons) b)	26000	20622	-20.68
VOC (1000 tons) b)	25000	20617	-17.53
Average pollutants (excl. CO_2) c)			-20.71
Average (adjusted for growth) d)			-25.60

Source: a) Adjusted from Rudlege and Vogan (1994); b) OECD-Environmental Data (1989 1995); c) arithmetic average of change for CO, PM10, NO_x, SO_x and VOC; d) previous row minus growth in CO_2.

[29] The longest time span for which both emission and abatement figures are available.

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However, these trends in abatement expenditures and in emissions do not establish an actual abatement relationship. In parallel to the decomposition of the pollution effects, three factors need to be taken into account when assessing the importance of abatement: first, economic growth (scale effect); second, a shift in the industrial structure away from emission-intensive industry towards generally cleaner services (composition effect); and finally, technological progress, reducing the need for material throughput (technology effect). Short of a more complicated analysis, the consumption of hydrocarbons can be taken as a proxy for these three combined factors. This approach is also likely to be consistent with the way emissions data tend to be constructed in practice, with total emissions output set as a multiple of fuel consumption.

From 1975 to 1992, CO_2 emissions rose by 4.9 percent (OECD 1995). Therefore, had emission technology stayed the same, one could have expected other emissions to rise similarly by 4.9 percent. Instead, they fell on average by 20.7 percent. One might therefore assume that the net effect of the 126 percent increase in abatement expenditure[30] is a decrease in emissions by 25.6 percent (20.7 % direct reduction plus 4.9% CO_2 trend). This value translates into a pollution-abatement substitution elasticity of 0.36. The value lies within the range that is given in the OECD literature review for energy-capital elasticity of substitution (Burniaux et al. 1992), and is taken as a central estimate for the model simulations. A sensitivity run will be undertaken with a value of 0.6 which results from making an analogous calculation based on PM10 emissions.

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[30] Economic growth and technical progress in abatement appear to be roughly in balance.

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An important implicit assumption of this approach is that this relationship holds across all sectors. There is no particular rationale for this assumption; however, given the lack of more specific information, the described methodology needs to serve as a proxy. A special problem concerns the treatment of the abatement elasticity in the presence of scale elasticity. Here the model assumes that scale economies apply only to production inputs labor and capital.[31] This means that pollution output will rise more than proportional to the inputs of capital and labor. However, as a consequence, there are economies of scale with respect to abatement expenditures.

4.2.4. Extension of Environmental Relationships to Canada and Mexico

It is not possible to estimate parameters for the other two countries analogous to the environmental sink function of the U.S., because independent and consistent data sources do not exist in particular for Mexico (and to a lesser extent for Canada). Instead, the U.S. data are adjusted to the situation in the other countries. For Canada, the hypothesis is simply that the country's emissions factors and abatement expenditures are identical to those of the US. In light of Mexico's completely different developmental status, this hypothesis is not defensible.

Following the argument made in the previous section, with identical emission technology per unit of capital employed, pollution output in Mexico should be proportional to the consumption of energy. Because energy consumption in the U.S. is 16.8 times higher than that of Mexico in the base year (OECD 1998), emissions in the U.S. would be higher than Mexican

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[31] Pollution follows the formula:
$$pollution(\lambda\,\overline{KP}, \lambda\,\overline{abate}, \lambda\,\overline{L}, \lambda\,\overline{IO}) = \lambda^{scale}\, pollution(\overline{KP}, \overline{abate}, \overline{L}, \overline{IO}).$$

emissions by exactly that factor. However, actual emissions for the U.S. are only between 2 and 10 times higher than those for Mexico.[32] If one takes a simple average of the figures for SO_2, NO_X, CO, and VOC, Mexican production is 3 times as polluting per output value as the US. Assuming a constant abatement elasticity of 0.36, we can conclude that abatement expenditure in Mexico is 5 percent of that in the United States per unit of production. If one assumes an elasticity of 0.6, Mexican abatement would be 15.5 percent those of the U.S. per unit of production.

Table 4-13: Pollution output in United States, Mexico, and Canada

	US	Mexico	Canada	Ratios US/MX
Value Add	566.2	43.3	78.4	13.08
Gross production	391.8	17.7	64.8	22.16
SO_2	842	403	95	2.09
NO_X	9718	955	1223	10.18
CO	81025	17152	7164	4.72
VOC/HC	10650	1753	908	6.08

Source: OECD-Environmental Data (1989 1995)

Alternatively, a set of emissions data for 14 sectors in Mexico would be available (van Tongeren et al. 1991). This is not used due to an apparent gap in the data quality and a limited sectoral breakdown of the emission figures. In any case, for this study the relative change in the level of emissions is more important than the absolute level of pollution.

Table 4-14 correlates the TSP per value added and abatement costs per unit of output with the capital-labor ratios and net export positions of each country. As a first impression most correlations are rather low. The highest positive correlation consists between pollution and

[32] Values for PM have not been used, because of differences in measurement techniques.

abatement. However, there are some hints that the relationship fits less for sectors with extreme values, as can be derived from the fact that the logarithmic correlation is substantially better than the linear one.

Table 4-14: Correlation matrix of various sectoral parameters *(logarithmic in Italics)*

	TSP	Abate-ment	K/L-ratio USA	K/L-ratio Canada	K/L-ratio Mexico	Net exports US	Net exports Canada	Net exports Mexico
TSP	1.000	0.305	0.149	0.284	0.264	0.078	0.092	0.083
Abatement	*0.789*	1.000	-0.069	0.052	-0.117	-0.042	0.121	0.017
K/L-ratio USA	*-0.039*	*-0.237*	1.000	0.710	0.549	-0.280	0.295	0.131
K/L-ratio Canada	*0.246*	*0.101*	*0.601*	1.000	0.218	-0.080	0.190	0.106
K/L-ratio Mexico	*0.161*	*-0.058*	*0.460*	*0.147*	1.000	-0.425	0.404	0.173
Net exports US	*0.002*	*0.015*	*-0.102*	*-0.069*	*-0.286*	1.000	-0.861	-0.490
Net exports Canada	*0.177*	*0.051*	*0.120*	*0.197*	*0.260*	*-0.861*	1.000	0.601
Net exports Mexico	*0.023*	*0.071*	*0.098*	*0.109*	*0.111*	*-0.490*	*0.601*	1.000

Note: a) Since for net exports no logarithms could be calculated, their original values are used also in the logarithmic correlation. b) For net trade an index is constructed by forming the ratio of net intra-NAFTA trade and domestic production.

Pollution intensity tends to be positively correlated with capital intensity, although the logarithmic correlation for the U.S. is slightly negative. By contrast, the sign of the relationship between abatement expenditure and capital intensity is mixed, with a negative sign for the U.S. and Canada, and a positive one for Mexico. The relationship of abatement and pollution intensity to net export positions is practically zero.[33]

[33] It may appear inconsistent that all three correlations for the trade index are positive although intra-NAFTA net exports cancel out by definition. However, the use of a trade index (net exports divided by output) can result in a statistical paradox, if countries differ in size. For instance, if Mexico has a trade surplus of 10 with the US, the index values for Mexico would be 0.2 and for the U.S. -0.001, if production in Mexico is 50 and in the U.S. is 1000.

The table also shows another example of the Leontief-Paradox, as it shows that the U.S. is importing capital-intensive goods. However, as was explained further up, this finding is consistent with the statistical results that establish the U.S. as a relatively labor-intensive country. By contrast, both Mexico and Canada are exporters of goods that are relatively capital-intensive. This fact, again, is in line with the findings of their relative endowments.

4.2.5. Calculation of Total Emissions

Technically, the calculation of total emissions is straightforward. It consists simply of multiplying the sectoral emission values just discussed by the sectoral estimates of value added. These figures are then summed over all sectors. However, for electricity and transport no emission factors per unit of output are available. Instead, these emission factors are calibrated for the U.S. to reflect total emission estimates for the respective shares of road transport and electricity production. This method implies that for these cases total and sectoral emissions had to be calculated simultaneously. The values thus calculated for the United States are used directly for the other two countries without making any further adjustments.

4.2.6. Relationship of Total Emissions to Air Quality

Of the multitude of air pollutants, this paper imputes only the consequences of small particles. Despite considerable remaining uncertainties, small particles are the air pollutant for which the effect on health is best researched due to broadly available statistics. Furthermore, the relationship between particulate emissions, air quality and health fits very well a linear function, which is not the case for more reactive pollutants such as NOx or ozone. This means that a doubling in emissions has a doubling of particle concentrations as a consequence. A linear relationship also holds for the effect of air quality on human health. For many other pollutants, one can discern a threshold effect: a concentration in the air below a certain value does not entail any measurable impact on human health, while higher concentrations can have considerable consequences. These non-linearities would not allow a simple aggregation, as it is possible for particles.

However, even particles are not without measurement problems. Notably, they do not constitute a single molecule, but are composed by a group of molecules, ranging from simple dust to SO_X. It is now well established that the damaging effect of particles on respiratory functions is the greater the smaller the individual particles are, because smaller particles enter the lungs more deeply than bigger ones. This insight leads to a variety of measurements differing by the size of particles included. They range from total suspended particles (TSP) to particles the size of 10 microns (PM10) to particles the size of 2.5 microns (PM2.5) or even smaller. A generally accepted relationship is to assume that PM2.5 constitutes half of PM10, which in turn constitutes half of TSP.

For the United States, using the average exposure, PM 2.5 lies roughly at 18$\mu g/m^3$ (Dockery *et al.* 1993; American Lung Association 1995). The same concentration is assumed for Canada. For Mexico, the derivation of concentration levels of total suspended particles follows Romieu, Weitzenfeld and Finkelman (1990). Average exposure of total suspended particles lies at 141 $\mu g/m^3$. In applying the approximation that one quarter of the TSP is PM2.5,[34] the average population in Mexico is exposed to a PM2.5 level 35.3 $\mu g/m^3$. Despite extremely high levels of exposure in some districts of Mexico city (reaching average TSP exposure of up to 500 $\mu g/m^3$) cautious calculations result in an average exposure to air

[34] This ratio is a cautious estimate, as in the United States the ratio is nearly one in three.

pollutants that is only twice as high as that of the US.[35] A one percent reduction in emissions reduces PM2.5 concentration in the U.S. by 0.018μg/m^3 and in Mexico by 0.0353 μg/m^3.

However, it is likely that the values for Mexico err at the side of caution, and there is evidence that the actual risk of exposure to PM2.5 may be higher than the numbers suggest. First, the ratio of PM2.5 to TSP in the U.S. samples is closer to 3 than to 4. There is no evidence that the ratio in Mexico should be higher. Collins and Scott (1993) cite evidence that the geographical situation of Mexico City is very conducive to the formation of very fine particles. Despite considerable difficulties in the reliability of measurements particle exposure appears to be at least eight times the levels detected in Chicago. Second, due to substantial differences in wealth between the North and the South of the NAFTA area, it is likely that Mexicans are less able to protect themselves against particle exposure than Canadians or U.S. citizens.

4.2.7. Health Effect of Air Quality

There exist a substantial number of epidemiological studies measuring the impact of particles on various indices of human health. These concern *inter alia* premature mortality; chronic bronchitis in adults; respiratory hospital admissions; emergency room visits; asthma symptom days; days with respiratory symptoms; acute bronchitis in children; restricted activity days, etc. (American Lung Association 1995) These are difficult to aggregate, since they contain substantial double counting. Most interesting and straightforward to interpret for purposes of

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[35] The average level of total suspended particles in Mexico city (38 % of population) lies at around 250 mg/m^3, those for other cities (38 percent) is assumed to be 125 mg/m^3, and for rural areas 25

economic modeling are restricted activity days or work loss. Ostro (1987) estimates that an increase in ambient concentrations of fine particles (PM2.5) by 1 mg/m^3 leads to 0.403 additional annual restricted activity days per worker.

The estimate might overestimate the isolated effect that particulates have on human health, because the econometric estimate by Ostro is likely to have captured also the effect of other pollutants, which are probably closely related to particulate pollution. However, the estimate will underestimate the health effect of total air pollution. In addition, the air pollution damage function neglects non-health-related externalities, such as the pollution of environmental media like soil and water, and omits damages to plants and materials. With certain caveats attached, the functional form can be used as an approximation of the health effects of pollution. Romieu, Weitzenfeld, and Finkelman (1990) have applied this method to pollution in Mexico city.

4.2.8. Effect of Health on Labor Productivity

The work loss estimates of Ostro can be used in a straightforward fashion to measure reduced labor output due to particulate emissions. This implies that a reduction in pollution by 10 percent would reduce annually sick days in the U.S. by 0.725 days, and would increase labor supply by 0.29 percent[36]. Identical figures are assumed for Canada. For Mexico, a ten percent reduction in air pollution leads to an increase in activity days by 1.42 days or 0.57 percent. It could be argued in particular for the case of Mexico that not all sick workers stay

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mg/m^3. If one quarter of these values consists fine particles (<2.5 mg/m^3), the average population in Mexico is exposed to a PM 2.5 level 31.5 mg/m^3.

[36] This is the equivalent of 0.725 sick days/250 work days per annum.

away from work. However, in any case, their productivity will be lower, and it can be argued that lack of treatment probably leads to a more drawn-out disease.

For purposes of a sensitivity analysis, the emission values of the toxicity-weighted index will be used. Following the calculations of the European Commission, total particulates cause only 70 percent of the total health damage of air pollution. Therefore, in this case, the health effects are increased accordingly by 43 percent[37] over those of the case taking into account only particulates.

4.2.9. Welfare Effect of Pollution

While the use of the equation for work loss is likely to be a sufficient proxy for measuring the effect of the air pollution externality on labor productivity, this factor underestimates the total welfare impact of pollution. Most notably it omits the impact of pollution on premature mortality. According the American Lung Association (1995) the cost of this factor is at least as high as the costs of morbidity. Therefore, a cautious adjustment is to assume that the welfare costs due to air pollution are double those for the work loss. This welfare component does not affect any other component of the model.

4.2.10. Political Income Elasticity for Pollution Abatement

The income elasticity for pollution abatement (ε) is not fixed. Variations in this parameter will be used to determine the sensitivity of the model simulations to the inclusion of this parameter. However, a central rate of 0.75 is assumed. This is based on two plausibility

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[37] 43% = (1-70%)/70%.

considerations. First, based on purchasing power parity, the U.S. is 3.73 times as rich as Mexico ($19,851/$5,323). If the assumption is correct that Mexico allows roughly three times the amount of pollution per unit of output, this implies an income elasticity of regulation 0.83 ($3.73^{-0.83}=0.33$).

Second, if the value were one or larger, it would mean that, in practice, pollution would be unlikely to ever become a problem in any country over its whole development path. This cannot be squared with the empirical observation of the inverted U-shaped pollution curve. By contrast, a somewhat lower value is compatible with the observed curve, if it is accompanied by the typical structural changes that occur during a country's development process. During an early development phase, a rising pollution level will accompany the economic specialization in the relatively dirty secondary sector. During a later development phase, a falling pollution level will accompany the growth of the relatively clean tertiary sector. If the elasticity were too low, only a steady increase in pollution would be observed, except in the case where dirty production shrinks not only in relative but also in absolute terms.

CHAPTER 5

SIMULATION RESULTS

This chapter presents the results of simulations with ETERNA. A first section proceeds by building up the full model in several steps. It starts by describing the simulation results of the trade liberalization scenario with nationally fixed capital stock, excluding any environmental interactions. The basic model is presented in two variants. The model is then extended to include the environmental externality. A second extension incorporates in addition induced regulation effects. Section 2 modifies the policy scenario of the first section by allowing intra-NAFTA capital mobility. Together with the first scenario, this scenario serves as reference case to assess the importance of various assumptions. Section 3 shows the importance of the petroleum sector in determining the results. Section 4 presents sensitivity runs on a number of calibration parameters. A fifth section analyzes different formulations of the country transformation equation. Section 6 illustrates the impact of unilateral actions in NAFTA countries. A final section presents a synopsis of the results and provides indicative conclusions.

5.1. Building up the Model Structure of the Central Case

5.1.1. Simple Trade Scenario with Internationally Immobile Capital

Policy scenario

To allow an understanding of the model mechanism it is useful to start with a simulation for which the environmental component is completely switched off. The underlying policy assumption is that trade barriers disappear for all intra-NAFTA trade.[38] The effects of reducing tariff and non-tariff barriers are quite distinct. Tariffs constitute both costs for importers and revenues for governments. To compensate for changes in revenues governments adjust the transfers to households. By contrast, the production of the public good and all tax rates, apart from tariffs remain constant. For non-tariff barriers, no compensation mechanism exists. By assumption, non-tariff barriers constitute a waste of resources that are used for rent seeking. A reduction in non-tariff barriers makes these resources available for final consumption or immediate production. Therefore, even without any changes in import volumes, the economies benefit from the increase in net output. By contrast, a tariff reduction leads to economic growth and increased welfare only because trade patterns adjust to reduced distortions.

Macroeconomic impact

The macroeconomic impact of the trade liberalization is listed in Table 5-1. All figures express percentage changes from the pre-NAFTA baseline. An evident effect is that both the absolute and relative trade integration of North America increases, as the strong rise in trade volume attests.[39] In terms of aggregate economic indicators, NAFTA has a positive impact on the North American economies. In relative terms, the greatest winners of the free trade agreement are Canada and Mexico, which realize GDP gains by roughly 2.5 % each. The increase in the USA is 0.67 %. This relative distribution of gains results from the differences in

[38] In the following the term NAFTA will be used, although the trade liberalization modeled properly also includes the earlier Canadian American Free Trade Agreement (CAFTA).

size and dependency of the three countries. However, in absolute terms, the U.S. is the main beneficiary. Out of a total gain of $41 bn, slightly less than two-thirds ($25.7 bn) takes place in the U.S., Canada enjoys a quarter of the benefits ($11.2 bn), and Mexico one-tenth ($4.0 bn).

Table 5-1. Macroeconomic effects of trade liberalization (immobile capital; no externalities)

	USA	Mexico	Canada
GDP	0.67	2.45	2.55
Material product	0.21	1.23	1.94
Capital return (real)	0.60	2.54	2.23
Wages real (net)	0.69	2.02	2.48
Labor supply	0.05	0.19	0.26
Private consumption	1.03	2.50	2.78
Exports	4.68	11.78	14.81
Imports	3.60	13.41	15.08
Terms of trade	-0.84	-2.66	-7.38

The change in private consumption is generally higher than that of GDP. The difference is explained mostly by the assumption of budget neutrality, which acts as leverage of GDP effects. For instance, if government consumption is 20 % and GDP increases by 1%, then the consumption effect would be expected to be of the order of 1.25 %.[40] Clearly, the leverage is smallest in Mexico due to a small government sector. Reduced government transfers resulting from tariff losses also have an influence.

The increase in real consumption is accompanied by higher factor rewards. As the relative increase in the economic pie is highest in Canada and Mexico, the largest relative

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[39] Differences in the changes of exports and imports are due to the relative trade and capital position of the countries in the base year with the U.S. running a balance of payment deficit and Mexico and Canada having a surplus. To preserve a constant external balance, exports and imports change a somewhat different rate.

[40] 1.25 % = 1 % / (1- 20 %)

increases can be found here. While in the U.S. and Canada benefits are relatively neutrally distributed between capital and labor, capital is the main beneficiary of trade liberalization in Mexico. This is consistent with the Stolper-Samuelson theorem, Mexico is a relatively capital-abundant country since, as was noted in Chapter 4.

A secondary effect of the increased purchasing power of wages is that labor supply and hence employment increases slightly in all three countries, between 0.05 and 0.26 %. Next to the allocation effect of trade, this provides additional economic growth as the absolute resource endowment rises. The mechanism also explains why wages increase less than might be expected (e.g. in the U.S. which is relatively labor-abundant).

Material Product

A value-based definition of output (such as GDP) is misleading for capturing environmental effects of trade liberalization, because only material flows are related to pollution. Instead, one needs an indicator that captures changes in the material throughput. Therefore, this paper makes the important distinction between GDP and material product, where the latter is calculated as gross output with constant output prices.

The substantive difference between the increase in the value of production and physical production is explained by the fact that even without actually producing much more (in physical units) in each individual country, the better allocation across countries allows a substantially higher consumption (in value terms). Several mechanisms can be identified to explain the magnitude of the differences between the values: First, the removal of trade barriers increases the purchasing power of consumers. It simply allows consumers to allocate better their consumption bundles. This leads to a higher increase in the value of consumption than the pure quantity of goods would suggest. Second, the removal of trade barriers allows for reallocation in the production process. This increases the efficiency in the production process, even without increasing the material throughput. These two factors simply reflect the theory of comparative advantage. A third factor is that a part of the trade distortion consists in non-tariff barriers. By assumption, non-tariff barriers lead simply to a waste of resources. These resources are now available for consumption (net output), which increases welfare even if production (gross output) were to remain unchanged.[41] While increasing GDP, all these mechanisms affect pollution only insofar as they might induce sectoral changes.

Sectoral Impact

The sectoral changes underneath the macro-economic aggregates are listed in Table 5-2. Despite an overall induced growth in all three economies, the 26 sectors are affected unevenly, with all states showing net winners and losers. The table reports material product, because of its importance for the calculation of emissions figures. Changes in production values are qualitatively very similar, because physical output follows relative price changes. However, in some instances, sectors will see their output decrease in material terms but increase in value terms.

Several sectors deserve particular mentioning. The first columns of each country in Table 5-2 show that agricultural production clearly moves away from Canada and Mexico to the United States. By contrast, petroleum production in the United States shrinks slightly, giving a boost to production in Mexico and Canada. Another important sector is transport equipment,

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[41] While this assumption concerning non-tariff barriers has some significance on the calculation of the welfare effect of trade liberalization, the impact on sectoral size and composition of the

where production increases substantially in the United States and Canada. Although each country has a few shrinking sectors, there is a general increase in manufacturing at the expense of services. This shift results from the fact that the removal of trade barriers practically only affects manufacturing sectors. In the data set a number of services are not even traded at all. The associated efficiency gain therefore moves the relative advantage towards manufactured products. In terms of the pollution effect of NAFTA, this may entail an upward bias, as services are relatively clean with the important exception of transport.

The second set of columns in Table 5-2 shows how the relative changes translate in absolute shifts in production. The values are calculated by multiplying the values of the first column with the output values of the base case. A monetary indicator for changes in material throughput may be a contradiction in terms. However, it presents the order of magnitude and importance of the sectoral changes in constant prices. Clearly, for both the United States and Canada, the effect of NAFTA is dominated by the transport equipment sectors. For these countries, the shrinking of services also play an important role. By contrast, the agricultural and the petroleum sectors, the two biggest in the economy, dominate change in the Mexican economy.

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economy is small, as the composition of resource waste is identical to consumption. Changes in the economy occur only insofar, as the increased real income affects the labor supply of an economy.

Table 5-2. Sectoral calculation of emissions impact of trade liberalization (immobile capital; no externalities)

	USA			Mexico			Canada		
	Out-put (%)	Out-put (bn $)	Emissions	Output (%)	Out-put (bn $)	Emissions	Out-put (%)	Out-put (bn $)	Emissions
Agriculture	1.66	3.25	0.000	-3.27	-0.73	0.000	-2.38	-0.79	0.000
Mining	0.18	0.04	0.007	1.70	0.07	0.161	1.16	0.14	0.205
Petroleum	-0.75	-1.42	-0.114	14.11	3.05	2.688	9.36	2.49	1.139
Food Processing	0.88	2.61	0.039	2.41	0.62	0.260	0.40	0.14	0.020
Beverages	0.80	0.39	0.000	3.01	0.12	0.003	0.84	0.05	0.001
Tobacco	-0.60	-0.19	0.000	1.47	0.01	0.000	-1.62	-0.03	0.000
Textiles	1.33	1.15	0.003	3.15	0.12	0.010	-0.06	0.00	0.000
Wearing Apparel	0.72	0.45	0.001	2.29	0.08	0.002	-0.06	0.00	0.000
Leather	3.34	0.29	0.001	-0.14	0.00	0.000	2.79	0.04	0.000
Paper	0.21	0.45	0.005	-0.82	-0.04	-0.012	-0.82	-0.28	-0.032
Chemicals	0.51	1.02	0.006	1.35	0.14	0.017	1.38	0.22	0.016
Rubber	0.52	0.64	0.001	0.12	0.00	0.000	6.40	0.45	0.005
Non-Metal Minerals	0.26	0.17	0.031	-0.57	-0.02	-0.127	0.84	0.06	0.093
Iron and Steel	0.93	0.68	0.019	3.75	0.15	0.139	10.33	1.07	0.377
Non-Ferrous Metals	0.74	0.52	0.016	-0.42	-0.01	-0.011	6.33	0.53	0.255
Wood & Metals	0.52	1.39	0.015	2.15	0.14	0.022	1.93	0.64	0.058
Non-Electr. Mach.	0.61	0.96	0.001	0.77	0.02	0.001	1.54	0.23	0.002
Electrical Machines	0.21	0.62	0.000	2.58	0.13	0.001	2.49	0.41	0.002
Transport Equip.	3.61	11.27	0.041	1.87	0.16	0.015	33.43	19.01	0.370
Other Manufactures	0.37	0.34	0.000	5.16	0.12	0.001	0.42	0.03	0.000
Construction	0.01	0.06	0.001	-0.34	-0.06	-0.011	-2.10	-1.69	-0.162
Electricity	0.37	1.00	0.099	3.76	0.15	0.268	-0.39	-0.07	-0.039
Commerce	-0.19	-1.67	0.000	-1.24	-0.55	-0.004	-2.70	-2.82	-0.006
Transp. & Comm.	0.02	0.07	0.003	0.15	0.03	0.024	-0.78	-0.50	-0.141
Finance & Insurance	-0.33	-3.69	-0.001	-1.55	-0.25	-0.001	-2.77	-1.69	-0.004
Other Services	-0.16	-3.38	-0.001	-0.25	-0.08	0.000	-1.26	-1.82	-0.003

Note: Emission figures are normalized such total emissions before trade liberalization in each country are 100.

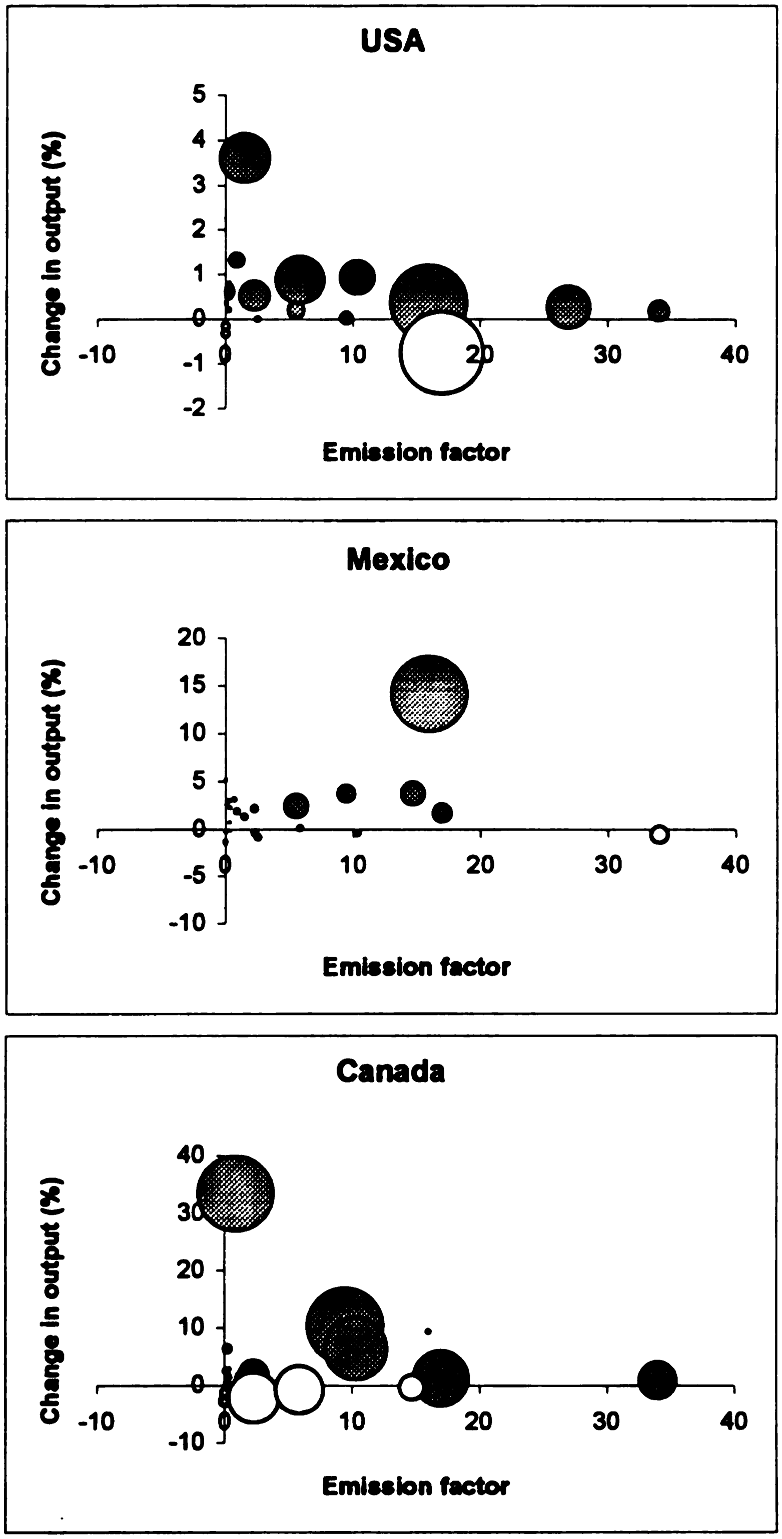
Environmental Impact

Importantly, material throughput also constitutes an intermediate step for the calculation of changes in the pollution levels. The final columns in Table 2 illuminate the environmental aspect of NAFTA. It is calculated by multiplying the sectoral changes with the pollution coefficients discussed in Chapter 4. Since the absolute level of pollution is not directly comparable between countries, numbers are calculated to set pre-NAFTA base emissions of TSP to 100.

Clearly, the change in the petroleum sector dominates the picture. The production shift away from the U.S. towards its neighbors has in its wake a substantial shift in pollution. Petroleum overwhelms all other changes in Mexico, with some additional impact from mining, food processing and electricity. This can be seen even better in Figure 5-1 where the size of the circles reflects the contribution of individual sectors to the overall emission change. If petroleum had an emission factor of zero, NAFTA's net result on pollution in Mexico would actually be negative. This aspect will be discussed further below.

In Canada, important contributions to the overall pollution effect are made by expansions in the mining and transport equipment sectors. Expansions in food processing, non-metal manufacturing, and electricity production, and contractions in petroleum influence the result for the U.S.

Figure 5-1: Contribution of Individual Sectors to Overall Emission Changes (ignoring regulation effect)



Note: Size of bubble represents overall emission change (Table 5-2). White bubbles represent decreases. Emission factor = index for TSP emissions per dollar of output value (Table 4-9).

The sectoral emissions changes sum up to the total pollution effect of the trade liberalization scenario (Table 5-3). Pollution in Mexico increases significantly (by 3.4 %), while that of Canada rises by 2.2 % and that of the U.S. rises only by 0.2 %. Table 5-3 further disaggregates the total emission impact into three components. The scale effect is equivalent to the change in GDP. Pollution would change by the same amount as GDP, if no other changes took place at the same time. This effect constitutes an important driver of the overall pollution effect. Values for Canada and Mexico are evidently higher than U.S. values.

Table 5-3. Emissions impact of trade liberalization (immobile capital; no externalities)

	USA	Mexico	Canada
Emissions	0.17	3.44	2.16
1. Scale effect	0.67	2.45	2.55
2. Allocation effect	-0.46	-1.19	-0.59
3. Composition effect	-0.04	2.19	0.21

Clearly, however, material product increases less than the production value. This means that GDP per unit of material product increases.[42] This increased allocation efficiency can be calculated as the difference between changes in GDP and physical product. In all three cases, this second effect reduces the impact of the scale effect substantially. However, there is no case where it overcompensates for the scale effect, because material product grows everywhere.

The composition effect constitutes a residual value, and is calculated as the change in pollution that is neither explained by the scale effect or the allocation efficiency effect. This effect provides a differentiated view. The production structure in the U.S. moves slightly

[42] This is similar in result to a dematerialization of the economy, which could occur due to technical progress.

towards less polluting sectors. In Mexico, the composition change is substantial. It contributes to an overall pollution increase of 2.2 %. The effect on Canada is also to increase pollution, although only by 0.2 %. However, as can be seen from Figure 5-1, the correlation between trade-induced sectoral specialization and emissions factors is far from systematic.

The ETERNA model setup leaves three possible factors to explain this composition effect. First, it could be the result of the relative factor abundance of the countries involved. As mentioned above, Mexico needs to be considered as capital abundant. This means that it tends to specialize in capital-intensive industries, of which the dominant petroleum sector is certainly a part. Second, since trade barriers were highest for the manufacturing sectors and low for services, a relative shift towards manufacturing could be expected at the expense of services. Third, differences in the regulatory standards among countries (and hence differences in capital costs) might reinforce a specialization of Mexico in pollution-intensive (or more precisely high-abatement cost) goods. However, abatement costs alone are inconsequential for trade patterns due to the calibration process. In the pre-NAFTA case, sectoral differences in the abatement costs are exactly balanced by differences in the productivity of capital. Otherwise, there would have been a difference in the net return of the sectors, implying that the economy could not have been in equilibrium.

5.1.2. Introducing the Externality

The simulations just presented calculate emissions with a simple add-on approach, without incorporating its associated externalities. Table 5-7 presents main effects of including externalities into the model. Compared to the case without externalities, four more reporting categories are introduced. First, the variable "health" denotes the change in the externality. Second, it is now useful to distinguish welfare and private consumption, because the two now deviate. Welfare is a composite of private consumption and health. Third, as additional information, the share of the externality in driving the overall welfare effect is reported. This figure includes production and hedonic effects. Finally, nominal and effective labor supplies are distinguished, because health has a direct impact on labor productivity.

Table 5-4. Trade Liberalization when Externalities are included: Welfare Change (immobile capital)

	USA	Mexico	Canada
Total welfare	0.94	2.23	2.41
Private consumption	1.02	2.45	2.74
Health	0.00	-0.19	-0.06
Externality (% welfare)	-0.94	-7.73	-4.56
Effective labor supply	0.05	0.01	0.20
Nominal labor supply	0.05	0.21	0.27

Effective labor supply consists of the nominal labor supply adjusted for the health effect. Changes in health affect the number of actual work hours only in a simple multiplicative way. The increase in the wage sum that occurs, because people are less sick does not act as a wage increase to which people adjust their labor supply. This is because both sides of the labor supply curve (leisure and labor) are affected equally by improving or worsening health.

The impact of including externalities on the economic structure itself is not very substantial, and therefore not reported. Nevertheless, the figures denoting the relative contribution of health to the overall welfare change show that the impact is not altogether negligible. In the case of constant pollution technologies, lower health reduces the welfare gain of NAFTA for Mexico by nearly 8 %. Even for the U.S. and Canada, health reduces the total benefits of liberalized trade by 0.9 and 4.6 %, respectively.

5.1.3. Introducing the Regulation Effect

A next step introduces a numerical formulation of the country transformation hypothesis. Abatement efforts are no longer constant. Instead, it is assumed that an increase in private consumption by 1 % is accompanied by regulations that decrease the permissible emissions per unit of output by 0.75 %.

Numbers reveal that the impact of introducing the regulation effect on environmental regulation on macro-economic aggregates are small (Table 5-8). The increased abatement expenditure acts to reduce overall production by 0.02 % in the case of the United States, while the reduction Canada's output is 0.06 %, and Mexico's production is unchanged. Although the growth impact of the regulation on the U.S. and Mexico are either small or non-existent, the reasons for contrast with Canada this are different. In the case of the U.S., the explanation is simply that the income growth induced by trade liberalization is smaller than Canada's. Consequently, the induced change in environmental stringency is also small. In this case, emissions per unit of output must be reduced by 0.74 %, while emission stringency in Mexico and Canada increases by 1.8 and 1.95 %, respectively.

By contrast, the reason for the small economic impact in the case of Mexico lies in the small level of pollution abatement in the country on the one hand, and the larger benefits of pollution abatement on workers' health on the other hand. Health improves by more than 0.1 % compared to a case that ignores the income effect. This increases effective labor supply by this amount, and therefore counteracts the resource loss implied by rising abatement costs.

Table 5-5. Central case simulation with immobile capital

	USA	Mexico	Canada
GDP	0.64	2.40	2.46
Material product	0.18	1.18	1.84
Capital return (real)	0.65	2.50	2.36
Wages real (net)	0.63	2.05	2.31
Effective labor supply	0.06	0.10	0.24
Nominal labor supply	0.04	0.19	0.24
Exports	4.68	11.73	14.75
Imports	3.60	13.37	15.00
Terms of trade	-0.86	-2.63	-7.32
Total welfare	0.95	2.30	2.43
Private consumption	0.99	2.45	2.66
Health	0.02	-0.09	0.00
Externality (% welfare)	3.58	-3.36	0.00
Emissions change	-0.65	1.52	0.00
1. Scale effect	0.64	2.40	2.46
2. Allocation effect	-0.46	-1.19	-0.61
3. Composition effect	-0.09	2.17	0.15
4. Regulation effect	-0.74	-1.80	-1.95

The introduction of the regulation effect changes the net pollution effect of the NAFTA scenario fundamentally. The U.S. registers now a noticable net reduction in pollution by 0.65 %. The emission effect for Canada disappears from an uncorrected value of over 2 %. Only Mexico continues to have a net increase in emissions. However, the values drop by more than half to 1.5 %.

An interesting aspect of the increased abatement effort is also that there are slight secondary effects on pollution. First, insofar as economic growth may be reduced, so is the scale effect on pollution. Second, there is a slight shift in the composition effect. In this case, it induces all three countries to move slightly towards less polluting industries.

The two welfare components are affected in opposing direction by the regulation effect. Gains in health counteract the decrease in consumption. Despite reduced private consumption in Canada and the U.S., overall welfare increases slightly. By contrast, Mexico realizes a health improvement while maintaining an unchanged consumption level.

The interpretation of the welfare results requires considerable caution because they obviously depend crucially on the externality estimates that are used. These are notoriously subject to uncertainties. As the parameters used in the simulations regard only a single aspect of the externality (the health effect of particulate air pollution), it is sure to underestimate the benefits of environmental regulation.

5.2. Introducing Factor Mobility

The model is now modified by making capital mobile across countries. The mechanisms at large are the same as described in the previous case. However, in this case capital moves to the place of highest nominal after-tax return across countries. This is not the case for real return to capital, which factors in the consumption deflator. In the simulation at hand, capital moves from the U.S. to Mexico, while Canada's position remains practically unchanged. Accordingly, the output of the latter two countries rises more than under the scenario with immobile capital. By contrast, production in the U.S. even contracts. Obviously, this shift in production has consequences for the pollution levels in the NAFTA countries.

Table 5-6. Central case simulation with mobile capital

Indicators	USA	Mexico	Canada
GDP	0.61	3.30	2.47
Material product	0.13	2.51	1.86
Capital return (real)	0.75	1.95	2.31
Wages real (net)	0.59	3.06	2.33
Effective labor supply	0.06	0.13	0.24
Nominal labor supply	0.03	0.35	0.24
Exports	4.27	16.94	14.84
Imports	3.46	14.72	15.05
Terms of trade	2.11	-3.25	-5.92
Total welfare	0.95	2.21	2.42
Private consumption	0.99	2.48	2.66
Health	0.02	-0.22	0.00
Externality (% welfare)	3.93	-8.71	-0.06
Emissions change	-0.71	3.79	0.03
1. Scale effect	0.61	3.30	2.47
2. Allocation effect	-0.48	-0.80	-0.61
3. Composition effect	-0.11	3.13	0.15
4. Regulation effect	-0.73	-1.82	-1.95

At first glance, the movement of capital appears to be counterintuitive. In particular, it contrasts with the previously established notion that the U.S. economy is relatively labor-abundant. Therefore, one could have expected that capital flows into the relatively capital scarce country. However, due to a larger relative importance of NAFTA, capital returns in Mexico and Canada rise substantially more than returns in the U.S. However, Canada's increase capital return is near exactly matched by a substantial worsening of its terms of trade, and hence, depreciation. Consequently, U.S. capital follows the higher return in Mexico. The differences in economic growth among the countries are therefore amplified.[43]

Compared to a scenario with immobile capital, the real return of American capital rises (by 0.1 %), while that of Mexico drops (by 0.55 %). As secondary effects, the capital movement causes wages in Mexico to rise 1 % more and those of the U.S. to rise 0.04 % less than in the case of immobile capital. Consequent changes in labor supply reinforce the shift toward production in Mexico. The production effect is a nearly full percentage point higher than with immobile capital.

While substantive in terms of production changes and trade, the difference between the scenarios with and without capital mobility is insignificant for the welfare effect. This is because the income loss or gain that results from the relocation of capital is compensated by profits that are transferred across borders.[44]

Capital mobility also affects the trade impact of liberalization. Two important differences to the case without mobility are worth mentioning. First, in the U.S. trade rises less than in the case of immobile capital, because capital flows act as a substitute for trade. Second, despite constant balance of payment requirement, exports and imports develop differently. This is

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[43] Barriers to capital movements are not explicitly modeled. The equilibrium assumption of ETERNA (or most CGE model) automatically presumed that an autonomous migration of capital has already equalized national rates of return before trade liberalization.

[44] Because in the case at hand, capital flows out of the labor-intensive economy (U.S.) into the capital-intensive economy (Mexico), the result could even be a decreased overall welfare. This paradox result can occur, because capital transfer entails an externality in the labor supply function. With identical labor supply elasticities in two economies, a dollar in a labor-intensive economy induces a higher increase in the labor pool than a dollar in the capital-intensive economy. In the case, where in addition health externalities exist, it can be demonstrated that capital mobility is actually welfare decreasing.

actually corresponds to the outflow of capital. The U.S. trade balance turns (more) negative, because of profit transfers from abroad. Correspondingly, Mexico's, balance of trade turns positive to finance these profit transfers.

It should be noted that the case of mobile capital only constitutes a long-term equilibrium. This does not mean that the path to this equilibrium would be straightforward. In particular, one would have to expect a J-curve effect, if the modeling predicts large capital transfers. If, for instance, the U.S. runs a trade deficit and finances it via profit transfers from investment in Mexico or Canada, the U.S. first would have to run a surplus to finance these investments, or has to borrow from elsewhere. If return on capital is 10 %, for every dollar deficit in the steady state, the country first would have to run a cumulative surplus of roughly 10 dollars to finance the necessary investments. A dynamic model might therefore arrive at substantially different results than the static one presented here.

The sectoral impact of the liberalization scenario reveals a picture that is qualitatively similar to the one for immobile capital (Table 5-7). Sectoral growth and contractions take place in more or less the same sectors as in the case for immobile capital (agriculture; petroleum; non-metal manufacturing; ferrous metals; and transport equipment). The obvious modification to the previous scenario is that in general sectoral values for the U.S. are smaller or more negative, while those for Mexico are larger, with Canada practically unaffected.

Table 5-7. Sectoral calculation of emissions impact of trade liberalization (mobile capital; no externalities)

	USA			Mexico			Canada		
	Out-put (%)	Out-put (bn $)	Emissions	Output (%)	Out-put (bn $)	Emissions	Out-put (%)	Out-put (bn $)	Emissions
Agriculture	1.41	2.76	0.000	-2.08	-0.47	0.000	-2.44	-0.81	0.000
Mining	0.04	0.01	0.001	4.71	0.18	0.444	1.14	0.14	0.200
Petroleum	-0.89	-1.67	-0.134	22.32	4.83	4.253	9.34	2.48	1.136
Food Processing	0.81	2.42	0.036	2.77	0.71	0.298	0.37	0.13	0.019
Beverages	0.81	0.40	0.000	3.20	0.13	0.003	0.85	0.05	0.001
Tobacco	-0.76	-0.24	0.000	1.86	0.01	0.000	-1.63	-0.03	0.000
Textiles	1.30	1.12	0.003	3.79	0.15	0.012	-0.04	0.00	0.000
Wearing Apparel	0.79	0.50	0.001	2.97	0.10	0.003	-0.03	0.00	0.000
Leather	3.30	0.28	0.001	0.38	0.01	0.000	2.79	0.04	0.000
Paper	0.17	0.35	0.004	0.23	0.01	0.003	-0.81	-0.28	-0.031
Chemicals	0.41	0.83	0.005	2.80	0.28	0.036	1.39	0.22	0.016
Rubber	0.42	0.52	0.001	1.23	0.03	0.001	6.43	0.45	0.005
Non-Metal Mineral	0.22	0.14	0.026	-0.19	-0.01	-0.042	0.84	0.06	0.093
Iron and Steel	0.80	0.59	0.016	5.02	0.21	0.186	10.35	1.07	0.378
Non-Ferr. Metals	0.65	0.45	0.014	1.04	0.02	0.028	6.35	0.54	0.256
Wood & Metals	0.47	1.26	0.014	2.85	0.19	0.029	1.94	0.65	0.059
Non-Electr. Mach.	0.50	0.79	0.001	2.31	0.06	0.003	1.52	0.23	0.002
Electrical Machines	0.13	0.38	0.000	4.84	0.24	0.003	2.51	0.42	0.002
Transport Equip.	3.52	10.99	0.040	3.39	0.30	0.028	33.50	19.05	0.370
Other Manufacture	0.35	0.32	0.000	5.94	0.14	0.001	0.44	0.04	0.000
Construction	0.01	0.04	0.000	-0.62	-0.12	-0.020	-2.11	-1.69	-0.162
Electricity	0.32	0.86	0.085	6.44	0.25	0.458	-0.40	-0.07	-0.040
Commerce	-0.23	-1.98	-0.001	-0.40	-0.18	-0.001	-2.71	-2.83	-0.006
Transp. & Comm.	-0.04	-0.15	-0.007	1.13	0.20	0.177	-0.80	-0.52	-0.145
Finance & Insuranc	-0.41	-4.56	-0.001	-0.96	-0.16	-0.001	-2.78	-1.70	-0.004
Other Services	-0.17	-3.60	-0.001	0.32	0.10	0.001	-1.27	-1.84	-0.003

Since changes in the pollution level are driven by changes in sectoral production, it is not surprising that pollution in the U.S. should rise less than in the case of immobile capital, while pollution in Mexico rises further. However, in this case the order of magnitude of the change in pollution levels has increased. Main factor is a much larger importance of the composition effect (driven by relocation of the petroleum industry).

In Mexico, the composition effect contributes over 3 percentage points of pollution growth, out of nearly 3.8 % in total. While loosing some of its industrial base, in terms of pollution, the U.S. is the winner, with a net reduction of 0.7 %. While in many aspects for the simulations the question of capital mobility is relatively unimportant, clearly for the environmental assessment of the trade liberalization, the question of capital mobility is crucial. In this case, NAFTA would not only lead to a relocation of pollution, but could potentially entail a net increase in pollution despite a large regulation effect. This would be the case in particular under the assumption that production in Mexico is substantially more polluting than in the U.S., However, it should be cautioned that to a substantial degree the changes discussed are due to a single sector, petroleum production.

5.3. Importance of the Oil Sector

5.3.1. Leaving out the Emission Effect

The simplest way to analyze the importance of the petroleum sector is by setting the emission coefficients of the sector to zero, while keeping the remaining scenario assumptions constant. This limits the scenario changes to the pollution composition effect. Table 5-8 compares the composition effect of the two central cases (for mobile and immobile captial) to one without the inclusion of the petroleum sector.

Table 5-8. Influence of the petrol sector on the overall emissions impact

	Immobile Capital			Mobile Capital		
	USA	Mexico	Canada	USA	Mexico	Canada
Compos. Effect incl. oil	-0.09	2.17	0.15	-0.11	3.13	0.16
Compos. Effect without oil	0.07	-0.31	-0.84	0.07	-0.59	-0.83
Total emissions incl. oil	-0.65	1.52	0.00	-0.66	3.90	0.21
Total emissions without oil	-0.49	-0.93	-0.98	-0.49	0.17	-0.77

Clearly, the omission of the sector causes important sign reversals across the board for the composition effect. While the composition effect for the U.S. changes from slightly negative to slightly positive, changes for the other two countries are more massive. Without petroleum, Mexico registers a composition effect that is reduced by around 2.5 % for immobile capital and even 3.7 % for internationally mobile capital. The composition effect of Canada drops roughly 1 %. In both Mexico and Canada, overall emissions now drop as a result of trade liberalization. There is little difference between the mobile and immobile capital scenario in this aspect. It is also important to note that without the petroleum sector, the central scenario delivers pollution improvements everywhere, with the exception of a negligible increase in Mexico, when capital is mobile.

5.3.2. Exclusion of Mexican Oil Sector from NAFTA

As a second way to examine the implication of exempting the Mexican oil sector from trade liberalization, the model was run leaving all bilateral trade barriers between Mexico and the other two states constant. To some extent, this reflects the actual situation that was negotiated in the NAFTA treaty, where a number of restrictions for investment in the Mexican oil sector remain in order to protect PEMEX (cp. Hufbauer and Schott 1993, p. 33-36). Table 5-9 reports the results under the assumption of internationally immobile and mobile capital.

Table 5-9. Exclusion of Mexican petroleum sector from NAFTA

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	0.59	1.94	2.46	0.62	1.11	2.57
Material product	0.17	0.85	1.84	0.19	-0.24	1.98
Capital return (real)	0.60	2.02	2.36	0.55	2.47	2.07
Wages real (net)	0.59	1.56	2.31	0.61	0.73	2.45
Effective labor supply	0.06	0.11	0.24	0.06	0.08	0.26
Nominal labor supply	0.04	0.15	0.24	0.04	0.02	0.26
Exports	4.34	12.18	14.74	4.56	7.84	15.14
Imports	3.32	13.53	14.99	3.39	12.40	15.11
Total welfare	0.90	1.66	2.43	0.89	1.72	2.44
Private consumption	0.94	1.75	2.67	0.94	1.72	2.69
Health	0.02	-0.04	0.00	0.02	0.07	-0.01
Externality (% welfare)	3.76	-2.10	-0.04	3.58	3.34	-0.42
Emissions	-0.65	0.69	0.02	-0.61	-1.14	0.20
1. Scale effect	0.59	1.94	2.46	0.62	1.16	2.57
2. Allocation effect	-0.42	-1.07	-0.51	-0.43	-1.35	-0.59
3. Composition effect	-0.12	1.15	0.17	-0.11	0.37	0.23
4. Regulation effect	-0.70	-1.29	-1.95	-0.70	-1.27	-1.97

Unsurprisingly, on a macroeconomic level the benefits of trade liberalization for Mexico are now about one half-percentage point less than in the base case. There is also a noticeable reduction in the trade benefits for the U.S. The reduced welfare gains are borne slightly more by capital owners than workers. Owing to the capital intensity of the sector, this could be expected. As trade between Mexico and Canada is minimal, Canada remains unaffected by the exclusion of the oil sector.

The limited NAFTA changes the overall pollution effect substantially less than the earlier sensitivity case that exempts the oil sector from the calculation of the pollution effect. None of the signs of the individual effects changes, although the net impact on Mexico's pollution level is only about one third of the central case. Important contributors are a lower scale effect, which is dampened by a reduced income effect, and a lower composition effect.

In the case of immobile capital, the drop in the composition effect could have been expected to be more substantial in light of the earlier discussion on the sector's importance. However, despite restrictions on trade, the oil sector in Mexico still expands by a substantial 6 % (compared to 14 % in the base case). This is due to growth in energy and oil-intensive sectors in Mexico and has obvious consequences for emissions.

For mobile capital, the effect of the change in the scenario is identical in direction, but substantially larger in magnitude. Mexico's GDP gains drop to a third of the central case. Capital flows to Canada and the United States instead, causing even the oil sector to shrink slightly. The production shift is accompanied by a shift in the pollution pattern. Mexican emissions drop by more than 1 %, instead of increasing by nearly 4 %. The sharply reduced scale effect and a substantially reduced composition effect dominate this change.

5.4. Sensitivity to Calibration Parameters

Chapter 4 described extensively that the construction of the model parameters had to rely on numerous assumptions and educated guesswork. Therefore, it is important to undertake a systematic sensitivity analysis to test the robustness and to explore the parameters that drive the results. The scenario assumptions will be those of the central cases (with and without international capital mobility) with individual assumptions varied one at a time.

5.4.1. Using a toxicity weighted emission factor

In this scenario, the use of TSP as an indicator for pollution is replaced by toxicity weights, i.e. an aggregate of TSP, SO_2, NO_2, CO, VOC (Table 5-10). The macro-economic impact of introducing toxicity weights is small (less than 0.02 % overall). This was to be expected from the discussion in section 5.1.2, which revealed a relatively limited macro-economic impact of the environmental component. Since the use of toxicity weights is simultaneously linked to an increase in the estimate for externalities it is evident that the trade benefits for countries that increase their pollution level (Mexico) become slightly less, while the trade benefits of pollution exporters (U.S.) become slightly higher. This is reflected in a higher share of health benefits in the overall result. The use of toxicity weights has also little noticeable impact on the direction of pollution flows. However, it should be mentioned that TSP makes up a significant component of the toxicity weights used.

Table 5-10. Replacing TSP in base case (immobile capital) with toxicity weights: Macroeconomic impact

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
Total welfare	0.96	2.26	2.43	0.96	2.12	2.42
Private consumption	1.00	2.44	2.67	0.99	2.45	2.67
Health	0.03	-0.13	0.00	0.03	-0.33	0.00
Externality (% welfare)	5.14	-5.14	0.28	5.21	-13.85	-0.35
Emissions	-0.67	1.60	-0.09	-0.67	4.03	0.11
1. Scale effect	0.64	2.39	2.46	0.61	3.29	2.47
2. Allocation effect	-0.46	-1.19	-0.61	-0.48	-0.80	-0.61
3. Composition effect	-0.11	2.26	0.06	-0.12	3.27	0.06
4. Income effect	-0.74	-1.79	-1.95	-0.69	-1.70	-1.78

5.4.2. Various Pollution Indicators

Table 5-11 analyzes whether the robustness between TSP as pollution indicator and toxicity weights is equally solid for its composite pollutants. The composition effect of the previous scenario with different pollutants largely supports the hypothesis that the composition effect is robust. Most values for the U.S. show a slight negative trend, while those for Mexico are strongly positive, while values for Canada are slightly positive. However, clearly carbon monoxides (CO) and small particles (PM10) do not fit the picture. CO causes sign reversals for Canada and significantly lower values for Mexico. PM10 even reverses signs for all countries. This is surprising in particular, because PM10 is an important constituent of TSP. One explanation for this may lie in the quality of the original data set, as we have hinted earlier at some sectoral anomalies in the relationship between PM10 and TSP[45]. A further explanation lies in the dependence of the results on only a few crucial sectors. Most notably, there is a major difference in emission values for PM10 and TSP in the petroleum sector.

Table 5-11. Comparison of the Composition effect for various pollutants

	Immobile Capital			Mobile Capital		
	USA	Mexico	Canada	USA	Mexico	Canada
SO2	-0.07	3.74	0.18	-0.07	5.55	0.20
NO2	-0.22	3.77	0.46	-0.24	5.57	0.46
CO	-0.18	0.40	-1.46	-0.19	0.65	-1.47
VOC	-0.08	3.05	0.68	-0.09	4.46	0.68
PM10	0.02	-0.15	-0.54	0.01	-0.21	-0.53
TSP	-0.09	2.17	0.15	-0.11	3.13	0.16
Toxicity	-0.11	2.26	0.06	-0.12	3.27	0.06

5.4.3. Abatement Elasticity

As central case assumption serves an abatement elasticity (the percentage reduction in pollution caused by a one % decrease in abatement expenditures) of 0.6. However, in Chapter 4 it was argued that the elasticity might be as low as 0.36. This would make increased abatement efforts more costly. For instance, a regulation effect of one % will increase abatement costs by 2.8 % instead of 1.6 %. However, the impact of this change results in only

[45] For some sectors, the reported value for PM10 was higher than for TSP, which is by definition not possible, because clearly small particles (PM10) are a subgroup of total suspended particles.

a small reduction of trade-induced growth, because the overall costs of abatement are less than 1.5 % of GDP (Table 5-12).

Table 5-12. Simulations with a low abatement elasticity

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
Total welfare	0.92	2.31	2.36	0.92	2.22	2.36
Private consumption	0.97	2.45	2.59	0.96	2.49	2.59
Health	0.02	-0.09	0.00	0.02	-0.22	-0.00
Externality (% welfare)	3.88	-3.40	0.10	4.23	-8.67	-0.00
Emissions change	-0.69	1.54	-0.05	-0.75	3.79	0.00
1. Scale effect	0.61	2.41	2.42	0.58	3.30	2.43
2. Allocation effect	-0.45	-1.19	-0.60	-0.48	-0.80	-0.61
3. Composition effect	-0.13	2.19	0.11	-0.15	3.13	0.12
4. Regulation effect	-0.72	-1.80	-1.90	-0.71	-1.83	-1.90

5.4.4. Abatement Function

Another potential source of bias may be that only capital is used for emission abatement. Alternatively, abatement efforts could reduce the value added of a sector. In other words, in each sector pollution abatement uses labor and capital in proportion. This has evident impacts on the incidence of pollution control. While in the central case the burden of pollution control is mostly borne by labor, in the alternative formulation it is more even. It will not be completely neutral, if abatement intensive industries are more capital-intensive. From the evidence provided in Chapter 4, we know that there is some, though not strong, correlation between the two. Results from the sensitivity run show that the impact of the assumption is so small that it can be safely neglected.

5.4.5. Labor Supply Elasticity

Of far greater importance is the sensitivity of the results to variations in the labor supply elasticity. To this end two extreme cases are considered: first, a completely inelastic, second, an infinitely elastic labor supply.

Zero elasticity

In the case of an inelastic labor supply, the scale effect of NAFTA is slightly reduced (Table 5-13). This affects most macroeconomic indicators by the same order of magnitude. However, there is a small shift in the structure of the economy. Since labor is more scarce compared to the base case, wages increase everywhere slightly, while rents fall. This leads all three economies to become more capital-intensive than in the central case. Since capital-intensive industries tend to be more pollution-intensive, there is a small composition effect towards pollution intensive production. However, a reduced scale effect and a reduced regulation effect lead the overall result on emissions to cancel out.

Table 5-13. Central case with labor supply elasticity of zero

	Immobile capital			Mobile capital		
	USA	Mexico	Can.	USA	Mexico	Can.
GDP	0.61	2.43	2.33	0.53	3.28	2.20
Material product	0.16	1.13	1.70	0.06	2.36	1.58
Capital return (real)	0.60	2.43	2.14	0.63	1.76	1.96
Wages real (net)	0.65	2.24	2.48	0.65	3.58	2.61
Effective labor supply	0.02	-0.09	0.00	-0.07	-0.39	-0.21
Nominal labor supply	0.00	0.00	0.00	-0.09	-0.18	-0.21
Exports	4.66	11.68	14.62	4.24	16.76	14.51
Imports	3.58	13.31	14.86	3.42	14.55	14.75
Total welfare	0.98	2.34	2.51	0.91	2.19	2.35
Private consumption	0.96	2.39	2.51	0.89	2.31	2.35
Health	0.02	-0.09	0.00	0.02	-0.21	0.00
Externality (% welfare)	3.41	-3.30	0.00	3.91	-8.75	0.01
Emissions	-0.64	1.52	0.00	-0.68	3.77	0.00
1. Scale effect	0.61	2.35	2.33	0.53	3.15	2.20
2. Allocation effect	-0.45	-1.19	-0.61	-0.47	-0.79	-0.62
3. Composition effect	-0.08	2.18	0.17	-0.08	3.13	0.18
4. Regulation effect	-0.71	-1.75	-1.84	-0.66	-1.70	-1.73

Infinite elasticity

The other extreme assumption is a perfectly elastic labor supply function, or, alternatively, the fixing of wage levels. Such an assumption increases significantly the net effect of NAFTA (three quarter of a % for the U.S. and Mexico, and 2 % for Canada). The economies become more labor-intensive with a relative trend towards less pollution-intensive production. In addition to increasing the regulation effect, this mitigates or even over-compensates the growth of pollution that is entailed by the increased labor supply. No difference is noticeable between the cases of mobile and immobile capital. Apart from their obvious impacts on labor supply and, hence, absolute scale effect of NAFTA, changes in the supply elasticity of labor have no impact that in any qualitative way changes the outcome of the model.

Table 5-14. Central case with infinite labor supply elasticity

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	1.40	3.07	4.48	1.30	4.28	4.84
Material product	0.92	1.79	3.84	0.79	3.30	4.31
Capital return (real)	1.75	3.37	5.59	1.81	3.17	5.35
Wages real (net)	0.00	0.00	0.00	0.00	0.00	0.00
Effective labor supply	1.27	2.32	3.80	1.16	3.30	4.19
Nominal labor supply	1.25	2.40	3.80	1.13	3.52	4.20
Exports	5.19	12.30	16.66	4.55	17.52	17.64
Imports	7.12	15.19	18.87	3.92	15.57	17.56
Total welfare	1.28	2.50	2.97	1.26	2.43	2.99
Private consumption	1.98	3.21	5.05	1.89	3.50	5.30
Health	0.03	-0.08	0.00	0.03	-0.21	-0.01
Externality (% welfare)	3.62	-3.05	0.08	4.00	-7.78	-0.52
Emissions	-0.89	1.50	-0.05	-0.97	3.70	0.30
1. Scale effect	1.40	3.09	4.48	1.30	4.15	4.84
2. Allocation effect	-0.48	-1.26	-0.62	-0.51	-0.81	-0.50
3. Composition effect	-0.34	2.11	-0.12	-0.35	3.01	-0.05
4. Regulation effect	-1.46	-2.34	-3.63	-1.39	-2.55	-3.80

5.4.6. Demand Elasticities

In the central scenario, a consumption elasticity of substitution of 1.5 is assumed, resulting in own price demand elasticities of roughly 1.4 for all sectors. A sensitivity simulation reduces the substitution elasticity to 0.9. The results of the scenario are presented in Table 5-15. As should be expected, lower demand elasticity reduces the overall effect, although one might be surprised that the impact of changing this parameter is so small. However, even with a zero elasticity of substitution for private consumption, a positive trade impact would result. This is one the one hand, because the import (or Armington) elasticity allows improvements in the allocation of production even if consumption is unchanged. Furthermore, the model contains a substitution elasticity of government consumption (set to 1) which would remain. In addition, the resource waste of non-tariff barriers plays a strong role. The benefit of reducing these barriers will be present, independent of the size of macroeconomic change.

Table 5-15. Simulations with reduced demand elasticity (0.9)

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	0.59	2.39	2.37	0.56	3.33	2.67
Material product	0.10	0.93	1.56	0.03	2.19	1.82
Capital return	0.67	2.41	2.39	0.81	1.86	1.86
Wages real (net)	0.55	2.16	2.34	0.49	3.12	2.58
Effective labor supply	0.05	0.14	0.25	0.04	0.16	0.28
Nominal labor supply	0.03	0.21	0.23	0.02	0.36	0.28
Exports	4.24	10.93	12.76	3.66	15.96	13.53
Imports	3.23	12.43	12.80	3.02	13.88	13.12
Total welfare	0.90	2.28	2.56	0.90	2.15	2.55
Private consumption	0.93	2.42	2.78	0.92	2.41	2.81
Health	0.02	-0.07	0.02	0.02	-0.20	0.00
Externality (% welfare)	4.21	-2.67	1.08	4.53	-8.20	0.05
Emissions	-0.73	1.20	-0.54	-0.82	3.37	-0.22
1. Scale effect	0.59	2.39	2.37	0.66	3.20	2.67
2. Allocation effect	-0.49	-1.42	-0.79	-0.53	-1.01	-0.85
3. Composition effect	-0.13	2.07	-0.03	-0.16	2.98	0.06
4. Regulation effect	-0.69	-1.78	-2.04	-0.69	-1.77	-2.06

The most important and obvious impact of a reduced elasticity of substitution is that most numbers are simply smaller than in the central scenario. In particular, the change in trade volume is reduced. However, at the same time some structural differences occur. Material product is relatively reduced, leading to lower pollution increases. This increases effective labor supply despite relatively sinking wages. The economy becomes more labor-intensive, because wages are affected more than rents. It can be noted also that the allocation effect is higher than in the central case, leading even to a slightly higher overall welfare in Canada. Considering the lower substitution elasticity this is somewhat counterintuitive. However, this effect is the result of an improvement in the terms of trade with the rest of world by 1 %, as the lower demand elasticity compared to the central case leads to a relative appreciation of the NAFTA currencies.

5.4.7. Elasticity of Scale

The inclusion of scale elasticities into the simulation also has a relatively small effect on the overall results. The results of setting scale elasticity to zero can be summarized in very simple terms. For all three countries, the macroeconomic impact of trade liberalization would be reduced by 10 to 15 %. There is also a slight, yet unsystematic impact on the pollution effect of trade liberalization. Capital mobility makes scale elasticity more important for the recipients of capital (Mexico), but does not alter the results much compared to immobile capital.

5.4.8. Revenue Recycling

A further set of sensitivity runs replaced the assumption that changes in government budgets are balanced through government transfers wit the assumption that budgets are balanced through changes in labor taxes. This mechanism reduces labor taxes, because the loss in tariff revenues is more than compensated by increased government revenues induced by overall economic growth. Therefore, labor supply and GDP increase. However, the net amounts of taxes that could be redistributed are small. Consequently, the impact of a switch to reducing labor taxes compared to lump sum transfer is very tiny. Even wages would be affected by less than 0.01 %.

5.5. Variations of the Regulation Equation

5.5.1. Various Regulation Elasticities

Clearly, the level of regulation elasticity is crucial in determining the net pollution effect of trade liberalization. Figure 5-2 shows the impact of increasing the income elasticity on the three NAFTA countries for internationally immobile and mobile capital. The graphs are normalized such that the trade impact with zero income elasticity is set to 1.

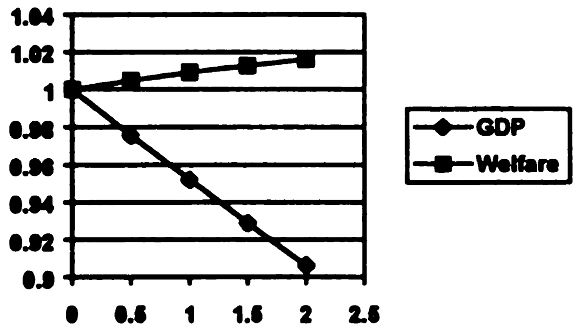
In the U.S. and Canada, the simulations indicate that the GDP impact of an increase in regulatory stringency is negative. For instance, in the U.S., a regulation elasticity of 2 would reduce the GDP gain by 10 %. By contrast, welfare increases slightly due to reduced pollution externalities.

For immobile capital, the cost of regulation and the increase in labor productivity appear to balance out exactly in Mexico. By contrast, overall welfare in the country increases substantially, due to the hedonic component of improved health. Capital mobility has little influence on this pattern, except that it widens slightly the discrepancy between GDP and consumption.

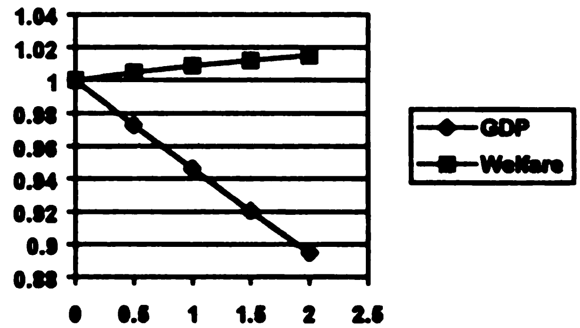
It should also be remarked upon that in a configuration with toxicity weights (implying higher externality values), the evaluation of various income elasticities of regulation changes. Now, for Mexico not just welfare, but also GDP rises with income elasticity, because the country has high externalities and low abatement costs. In the other two countries, GDP still drops, as stringency increases. However, in both cases the welfare effect is more positive. Of course, ultimately, the welfare effects are largely a function of the starting assumptions. The exact values are also not relevant for the discussion of this paper, which does not focus on the question of an optimal regulation level but on the consequences of Figure 5-3 shows the pollution effects of increased regulation elasticity. In all cases the curve for total emissions drops somewhat steeper than that for the regulation effect. However, the additional impact by output and composition effects are negligible in practice. For each country, one can derive the threshold value above which NAFTA will be pollution reducing. (Evidently, this will differ by type of pollutant). For the U.S., the value is very low at about 0.2; for Canada the value is

Figure 5.2: The impact of various levels of regulation elasticity on GDP and welfare (Zero elasticity case set to 1)

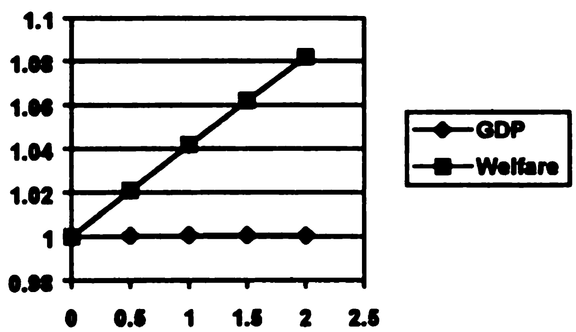
a) USA (immobile capital)



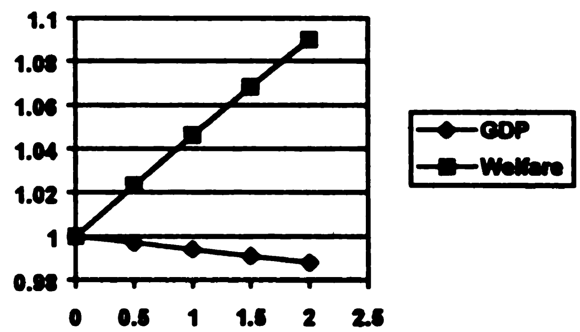
b) USA (mobile capital)



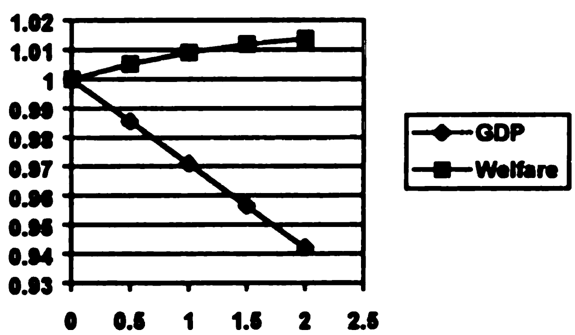
b) Mexico (immobile capital)



d) Mexico (mobile capital)



e) Canada (immobile capital)



f) Canada (mobile capital)

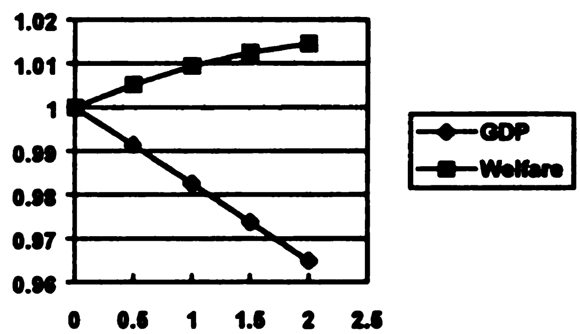
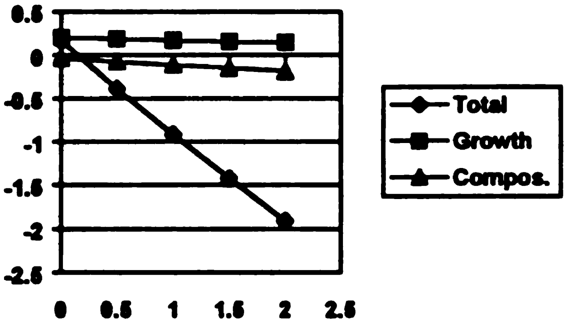
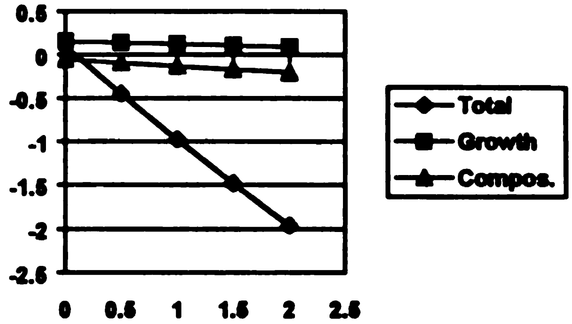


Figure 5.3. The impact of regulation elasticity on total pollution, growth and composition effect (percentage changes from pre NAFTA base case)

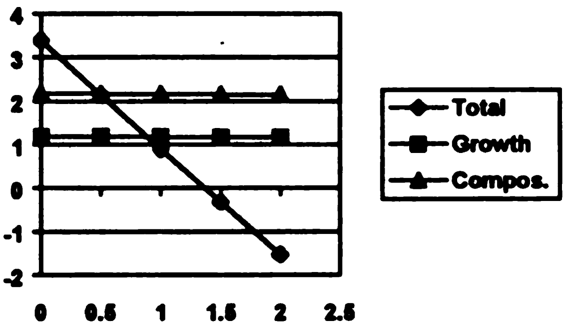
a) USA (immobile capital)



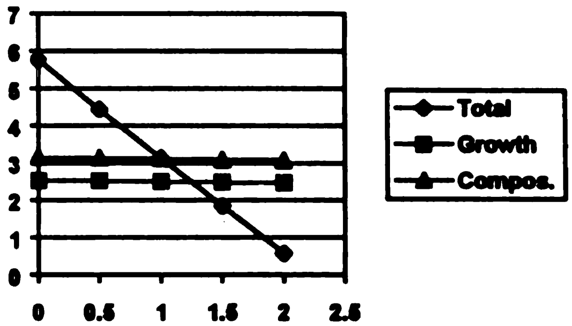
b) USA (mobile capital)



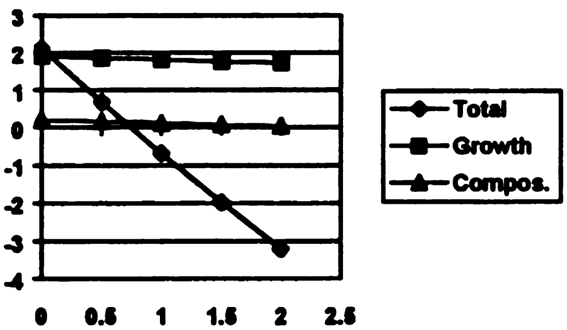
c) Mexico (immobile capital)



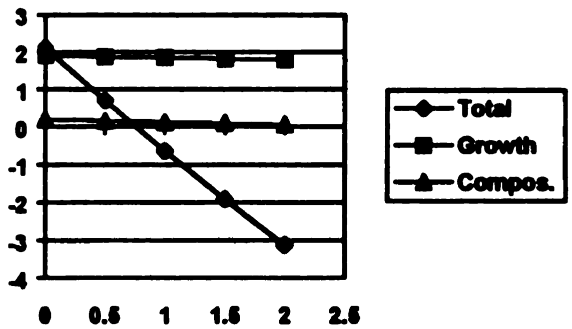
d) Mexico (mobile capital)



e) Canada (immobile capital)



f) Canada (mobile capital)



around 0.75. Mexico, by contrast, would need values between 1.4 and 2.2. However, there may be good reasons to believe that the elasticity in Mexico is higher than in the other two countries, due to external and internal pressures, and the simple fact that the country appears under-regulated.

5.5.2. Policy Function Connected to Wages

The paper of Bommer and Schulze (1996) is based on the assumption that the government balances the interests of labor against those of the environment. To assess this hypothesis, sensitivity runs link the regulation stringency to real hourly wages instead of private consumption. Table 5-16 shows the pollution result when a regulatory elasticity of 0.75 is applied. The influence on other macroeconomic variables is so small that it is not worth reporting on.

Table 5-16. Regulation effect as function of wages

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
Emissions	-0.37	1.80	0.25	-0.40	3.38	0.27
1. Scale effect	0.64	2.40	2.46	0.62	3.31	2.48
2. Allocation effect	-0.47	-1.19	-0.60	-0.48	-0.79	-0.61
3. Composition effect	-0.07	2.18	0.16	-0.09	3.13	0.16
4. Regulation effect	-0.48	-1.53	-1.72	-0.46	-2.22	-1.73

A priori the simulations will be different from the central case only insofar as wages and private consumption differ. As in all cases wage increases are somewhat less than welfare increases, the regulation effect under the Bommer-Schulze assumption would be accordingly smaller. Notably, Canada now reports a pollution increase by 0.25 %.

However, small as they may be the difference between the assumptions applied in the central case and the one applied here overestimate the true importance of the hypothesis. More important is actually the assumption of keeping government consumption fixed. The policy function is based on the development of private consumption. If government consumption is fixed, for a given GDP increase private consumption must increase at a higher percentage rate than GDP. With government consumption share at around one fourth (this excludes transfers), the leverage effect for Canada and the U.S. is about one third. For Mexico, this is somewhat smaller. For this reason, the difference between the Bommer-Schulze assumption and the one applied here should not be exaggerated. The results would be very similar, if the same implicit elasticities were used in both cases.

5.5.3. Quantitative Restrictions

An alternative presentation of the regulation problem could be in the form of quantitative restrictions of emission by sector. The government would set the permissible emission per unit of output such that each sector would achieve exactly the same percentage reduction in total emissions independently of whether it might be expanding or contracting as a result of the regulation. Sectors that increase their output would therefore face relatively tougher constraints, while emission limits for contracting sectors are relaxed. The effect of such a regulatory mechanism is reported in Table 5-17.

Table 5-17. Definition of restriction target in quantities of each sector

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
Emissions	-0.73	-1.81	-1.93	-0.72	-1.85	-1.94
1. Scale effect	0.63	2.43	2.45	0.59	3.32	2.51
2. Allocation effect	-0.46	-1.21	-0.70	-0.47	-0.80	-0.67
3. Composition effect	N/A	N/A	N/A	N/A	N/A	N/A
4. Modified Regulation effect	-0.90	-2.99	-3.63	-0.84	-4.28	-3.73

The values shown here are quite different from those of the central case, which is essentially the result of a higher *de facto* regulatory stringency as well as a different interpretation of the results. Most importantly, the scenario assures that the emissions reductions desired by a country *ex ante* will actually occur *ex post*. In other words, the emissions impact of trade liberalization has a guaranteed negative sign. This is the result of two changes compared to the regulatory setup in the central case. First, the composition effect must be zero. By definition, relative differences in growth across sectors are exactly counteracted by changes in regulatory stringency. Second, the implicit regulation impact is substantially stronger than in the central scenario. In the central case, the regulation effect is fixed, making the emissions effect a residual variable. In the case of quantitative restrictions, the emission effect is fixed, leaving the regulation effect to be determined. Since for this inherently different mechanism the same elasticity of 0.75 is applied, the effective stringency is higher than in the central case, which prohibits a direct comparison of the effectiveness of the different regulatory regimes.[46] As a secondary effect of this increased stringency, there is a slight reduction in growth, as could be expected from the discussion in the previous section.

Therefore, a quantitative regulation setting is not very interesting and would not need the analytical tool of an integrated CGE model, because the effect could simply be calculated externally. Nonetheless, such a scheme might conceivably be employed to mitigate the impact of trade liberalization, as losers are treated more leniently than winners. However, this would leave open a number of questions concerning the implicit formulation of environmental policies.

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[46] Comparable stringencies would require fixing identical joint impacts of income on regulation minus growth. However, this would not solve the fundamental dilemma that the overall emissions effect is a foregone conclusion.

5.6. Unilateral Actions

5.6.1. Unilateral Changes in Abatement Intensity

A potential difficulty in interpreting impact of regulation elasticities consists in the assumption that changes occur in all three countries at the same time. This assumption leaves two open ends. First, since the regulation level for Mexico is substantially lower than in the United States or Canada, even an increase that is relatively higher in Mexico than in the other countries might still increase the absolute attractiveness of the country for polluters. Second, simultaneous changes in abatement effort do not allow an analysis of a unilateral increase in regulations.

Simulations of a unilateral reduction in unit emissions by one third illuminate this aspect. This increase in the stringency is *ex ante* only. To the extent that the scenarios might change private consumption, the *ex post* figure might deviate from this. There is no discernible difference between the impact of a unilateral increase in regulation with an without NAFTA. For this reason, only the pre-NAFTA set is reported. Therefore, in practice, NAFTA does not limit the possibility to set environmental standards in any of the countries.

The direct impact of the increase in U.S. regulatory stringency is for GDP to sink by 2.3 % (Table 5-18). The incidence of the regulation falls exclusively on wages (-4.76 %), because effective labor supply increases by 0.35 % du to a large improvement in health. By contrast, capital actually benefits due to the demand for abatement equipment and the increased labor supply (+3.17 %). The U.S. economy becomes more labor-intensive.

The pollution effect of the regulation is noticeably higher than what would be expected by the regulation effect only. Next to the contracting GDP, the composition effect plays a substantial role, as production moves away from abatement and pollution-intensive goods.

Most of this reflects actual changes in consumption, only relatively little of the composition effect is counterbalanced by concomitant increases in pollution-intensity in Mexico and Canada. For these two countries, the effect of production relocation is much too small to compensate them for the loss they suffer as a result of the changes in the U.S. Due to a simultaneous increase in import prices for U.S. products and a contraction in their largest export markets, Mexico and Canada suffer GDP losses of more than 0.3 %.

Table 5-18. Unilateral reduction in unit emissions by one third in the United States

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	-2.28	-0.29	-0.29	-2.20	-1.01	-0.83
Material product	-2.22	-0.02	-0.08	-2.10	-1.20	-0.80
Capital return (real)	3.17	-0.31	-0.28	2.93	0.22	1.17
Wages real (net)	-4.76	-0.27	-0.27	-4.67	-1.13	-0.94
Effective labor supply	0.35	-0.05	-0.04	0.36	-0.09	-0.14
Nominal labor supply	-0.71	-0.03	-0.02	-0.69	-0.18	-0.16
Exports	-0.50	0.31	-0.08	0.43	-4.54	-2.06
Imports	-0.59	0.33	0.02	-0.30	-1.03	-0.62
Total welfare	-1.06	-0.36	-0.35	-1.06	-0.24	-0.34
Private consumption	-2.84	-0.35	-0.36	-2.83	-0.35	-0.46
Health	1.07	-0.03	-0.01	1.06	0.09	0.01
Externality (% welfare)	-174.94	6.67	6.14	-174.70	-32.59	-7.35
Emissions	-36.80	0.48	0.42	-36.69	-1.59	-0.50
1. Scale effect	-2.28	-0.29	-0.29	-2.20	-1.01	-0.83
2. Allocation effect	0.06	0.27	0.21	0.09	0.01	0.03
3. Composition effect	-4.42	0.23	0.23	-4.37	-0.65	-0.05
4. Regulation effect	-32.37	0.27	0.27	-32.37	0.26	0.34

The difference between simulations with internationally mobile and immobile capital is surprisingly small for the United States. The U.S. is actually better off with mobile than with immobile capital, because it attract capital from neighboring countries. This might be contrary to intuition, as one could expect that the increased abatement costs leads capital to flee the country. However, since capital returns in the U.S. actually increase due to a higher effective labor supply and lower wages. (It can be demonstrated that the two effects cancel out, when the health effect of reduced emissions is forced to zero.)

The net capital migration to the U.S. because of the regulation causes the composition effect in all three countries to turn negative. This is a crucial difference. In the case of immobile capital, trading partners counteract the composition effect in the regulating country. In the case of mobile capital, the allocation effect is exported to the trading partners. For this reason, the welfare and income effect in Canada is substantially more negative than for immobile capital. However, Mexico benefits due to lower pollution levels.

Table 5-19 shows the effect of a unilateral regulatory increase in Mexico. Given the appropriate adjustment for the size of the economy, the effect of increased regulation in Mexico is largely the same as that of a unilateral action by the United States. GDP drops in all three countries. However, in the case of Mexico, low abatement costs and high externalities actually lead to an increase in overall welfare in the country. Again, owners of capital become better off than without the regulation. Due to its small size, the influence Mexico has on the other two countries is minor but slightly negative. The composition effect induced in all three countries has the expected sign, but is small. Capital mobility reinforces the effects that occur in the case of immobile capital. In the case at hand, the favorable effect of regulation on capital return leads to a noticeable inflow of capital to Mexico. Finally, Table 5-20 reports the Canadian case, which is *mutatis mutandis* the same as that of the United States.

Table 5-19. Unilateral reduction in unit emissions by one third in Mexico

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	-0.004	-0.188	-0.002	-0.006	-0.135	-0.002
Material product	-0.001	-0.363	-0.001	-0.003	-0.288	0.000
Capital return (real)	-0.004	0.359	-0.001	0.002	0.328	-0.002
Wages real (net)	-0.004	-2.860	-0.001	-0.006	-2.809	-0.001
Effective labor supply	-0.001	1.539	0.000	-0.001	1.544	0.000
Nominal labor supply	0.000	-0.383	0.000	-0.001	-0.374	0.000
Exports	0.010	-0.125	-0.002	-0.013	0.176	0.000
Imports	0.014	-0.214	-0.001	0.007	-0.131	0.000
Total welfare	-0.005	1.012	-0.002	-0.005	1.009	-0.002
Private consumption	-0.005	-0.238	-0.002	-0.005	-0.236	-0.002
Health	0.000	1.930	0.000	0.000	1.925	0.000
Externality (% welfare)	5.822	165.272	8.759	2.053	165.466	7.907
Emissions	0.006	-33.855	0.003	0.002	-33.769	0.003
1. Scale effect	-0.004	-0.188	-0.002	-0.006	-0.135	-0.002
2. Allocation effect	0.004	-0.225	0.001	0.003	-0.153	0.001
3. Composition effect	0.002	-0.539	0.002	0.001	-0.483	0.002
4. Regulation effect	0.004	-33.254	0.001	0.004	-33.254	0.002

Table 5-20. Unilateral reduction in unit emissions by one third in Canada

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	-0.04	-0.01	-1.76	-0.11	-0.13	-1.05
Material product	-0.01	0.00	-2.21	-0.10	-0.15	-1.28
Capital return (real)	-0.04	-0.01	3.99	0.15	0.03	2.11
Wages real (net)	-0.04	-0.01	-4.87	-0.12	-0.14	-4.04
Effective labor supply	-0.01	0.00	0.25	-0.02	-0.01	0.41
Nominal labor supply	0.00	0.00	-0.76	-0.02	-0.02	-0.58
Exports	0.04	0.00	-0.81	-0.64	-0.58	1.83
Imports	0.13	0.00	-1.41	-0.08	-0.14	-0.58
Total welfare	-0.04	-0.01	-0.76	-0.05	-0.02	-0.76
Private consumption	-0.05	-0.01	-2.44	-0.07	-0.04	-2.32
Health	0.00	0.00	1.02	0.00	0.01	1.00
Externality (% welfare)	6.57	13.38	-228.64	-6.20	-52.31	-224.72
Emissions	0.06	0.04	-35.17	-0.06	-0.23	-34.36
1. Scale effect	-0.04	-0.01	-1.76	-0.11	-0.13	-1.05
2. Allocation effect	0.03	0.01	-0.45	0.01	-0.02	-0.22
3. Composition effect	0.03	0.03	-1.78	-0.01	-0.11	-1.43
4. Regulation effect	0.04	0.01	-32.51	0.05	0.03	-32.55

5.6.2. Sectorally Optimal Regulation

A further interesting simulation run is to test what would happen, if countries introduced an optimal regulation that equalizes the marginal abatement costs across sectors. Table 5-21 shows the result of such a regulatory change. The abatement values are calculated to meet the same emissions level as in the pre-NAFTA scenario for a constant production structure. The level of stringency is not adjusted to account for sectoral changes that are introduced by the improved regulation. For this reason, the overall pollution effect differs from zero.

Table 5-21. Optimal sectoral regulation level

	Immobile capital			Mobile capital		
	USA	Mex.	Can.	USA	Mex.	Can.
GDP	0.59	0.26	0.52	0.68	0.51	0.59
Material product	0.63	0.25	0.69	0.62	0.58	0.62
Capital return (real)	-0.54	0.15	-0.72	-0.53	0.01	-0.59
Wages real (net)	1.05	0.47	1.15	1.04	0.72	1.08
Effective labor supply	0.09	0.07	0.16	0.09	0.08	0.15
Nominal labor supply	0.14	0.06	0.16	0.14	0.10	0.15
Exports	0.36	0.18	0.50	0.32	1.50	0.31
Imports	0.39	0.21	0.63	0.37	0.57	0.57
Total welfare	0.63	0.31	0.75	0.63	0.30	0.75
Private consumption	0.80	0.33	0.87	0.81	0.34	0.85
Health	-0.05	0.00	0.00	-0.05	-0.03	0.00
Externality (% welfare)	-14.34	0.84	-0.34	-14.26	-7.50	0.22
Emissions	1.73	-0.05	0.05	1.73	0.44	-0.03
1. Scale effect	0.59	0.26	0.52	0.68	0.51	0.59
2. Allocation effect	0.03	-0.01	0.17	-0.06	0.07	0.03
3. Composition effect	1.71	-0.06	0.01	1.71	0.12	-0.02
4. Regulation effect	-0.60	-0.25	-0.65	-0.60	-0.26	-0.64

Since sectoral differences in the marginal abatement costs are quite large, induced growth is substantial and reaches 0.6 to 0.7 % of GDP in the U.S. The gain for Mexico is only

0.26 to 0.5 % due to a smaller level of abatement expenditures. The improved regulation also induces significant composition changes, which, in the United States, increases pollution compared to the base case. This could mean that the more polluting sectors are relatively over-regulated, and benefit from the lower burden that is now imposed on them. An alternative explanation could lie in the incidence of the regulatory change. It can clearly be seen that the capital rents drops because of reduced demand for abatement capital. (The only country where capital does not suffer is Mexico, where benefits from trade with the United States are more important than reduced capital demand.). By contrast, labor benefits from the better regulation through higher wages. Consequently, the NAFTA economies move into the direction of increased capital intensity, which influences the sectoral emissions effect.

5.6.3. Some Considerations on the Optimal Emissions Level

In this context, one could also calculate an *optimum optimorum*, for which not just the relative level of regulation would have to be fixed, but also the absolute emissions. While an analytical solution is rather complex, this could be done in a simple search procedure by increasing the stringency levels until the maximum welfare level is attained. However, in light of the great uncertainties attached to the values of externalities, such a calculation itself does not provide useful insights. Instead, we limit ourselves here to some theoretical considerations.

For the functional form chosen for the overall utility level[47], it can be demonstrated that the optimal share of abatement expenditures in the total economy is constant. This is shown in

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[47] Utility (U) is a composite of material well-being (M) and health (H) according to the equation $U = MH^{\eta}$.

the Appendix. This optimal share of abatement expenditure rises when the externality is high and abatement costs are low. The utility function implies a unitary elasticity of pollution abatement expenditures with respect to income increases. This means that the optimal regulatory elasticity of income would be zero. The reason is that the for the selected functional form, both marginal costs and benefits increase in proportion to income, leaving the benefit-cost ratio of unit emissions unchanged.

However, for several reasons, the functional form should not let one presume that the income elasticity of regulation is zero. First and importantly, the functional form is arbitrarily chosen for illustrative purposes. It could be changed into a linear expenditure function with minimum consumption levels to change the income elasticity of health such that a certain income elasticity of regulation is implied. Preference is given to the present functional form, because it is simple and has no influence on actual behavior. Furthermore, precise information is unavailable on which to base a different functional form. Second, the function shows the importance of good regulation. A move towards a better type of regulation (e.g. the sectoral adjustment simulated further up) leads both to a lower pollution level and an increase in overall abatement expenditures. Third, the zero elasticity result only holds for an optimum path of regulation. It is highly doubtful that any country has achieved this. To the extent that regulation levels are below the optimum, one would expect a higher increase in regulation. Fourth, the functional form assumes implicitly that no structural change occurs in the economy, which would alter the benefit cost relationship of abatement. However, the main effect of trade liberalization lies exactly in a change in the economy. Fifth, the formulation reflects preferences and not a political function, which might be different. Sixth, technical progress in abatement technology is not included in the calculus of the equation, which would lead to a higher level of abatement and lower emissions. With these limitations in mind, a tentative resume of the simulation results is drawn in the next section.

5.7. Tentative Conclusions

This chapter presented model simulations of trade liberalization under a large variety of different assumptions. Before coming to an overall assessment on the three empirical hypotheses on trade and environment, a brief synopsis is presented here. Conclusions can be drawn, first, on the usefulness of the analytical tool itself; second, on the concrete case of the environmental impact of NAFTA; third, on the importance of various factors for determining the overall results; and fourth, on recommendations for environmental policy in an open economy. These four will be briefly addressed here.

1. Usefulness of the analytical tool

The simulations have demonstrated that the issue of trade and environment can be successfully addressed in a in a CGE model. Important limitations to this approach can be found less in the modeling itself than in the lack of reliable data. However, the possibility of data construction in the CGE approach makes the data problem much less constraining than in alternative methods.

A particular advantage of the modeling approach chosen is that it allows a decomposition of the underlying processes that determine the overall environmental result. The disaggregation into an effect on growth, allocation efficiency, composition, and regulatory stringency is also of great assistance in identifying important data and policy parameters.

2. Environmental impact of NAFTA

The simulations allow robust findings for the analysis of trade liberalization. Of particular importance in this context is the model-endogenous regulation-setting. The model runs indicate that concerns that trade liberalization might lead to an environmental erosion are largely misplaced for two reasons.

First, the correlation between trade liberalization and specialization in polluting industry is weak. The paper finds that, as a result of NAFTA, Mexico specializes relatively in polluting sectors, the United States in less polluting ones, with mixed results for Canada. However, this specialization is far from systematic and is dominated by the trade impact on the location of just one sector (oil and petrochemical industry). For this trade specialization, the importance of differences in environmental stringency among countries is small. Instead, the trade specialization is strongly dominated by differences in the relative capital-labor endowments of the countries. The findings mean in practice, that trade and environmental policies can be pursued relatively independent from each other.

Second, it is demonstrated that even in the country that ends up specializing in the relatively polluting sectors (in this case Mexico), trade liberalization results in at most a small deterioration of the environment, if reasonable assumptions are employed for an income-induced demand for abatement effort. In many cases, it would therefore be counterproductive to erect trade barriers, if one wanted to preserve the environment at home and abroad.

3. Importance of various economic parameters

The analysis allows to identify the factors that are important in driving the results. Table 5-22 summarizes the findings of the various sensitivity runs. In terms of their importance, issues concerning model structure and data can be sorted into a group of important factors and a group with low or predictable effects. To the group of important factors belong capital mobility, the importance of the oil sector, the choice of pollutant, and, evidently, the regulation elasticity. The impact of the first three factors on overall pollution is mainly through their influence on the composition effect, while regulations obviously reduce emissions directly.

Other factors, such as the value of the externality, the abatement elasticity or functional form, labor supply elasticity, and economies of scale, have a small impact on the modeling results. Demand elasticities can have a substantive impact on the overall magnitude of the trade impact, but leave the structure of the emissions impact unaffected.

4. Policy results

The analysis of policy variables allows three important conclusions. First, the regulation elasticity is of essential importance for the determination of net results. In the central case, the inclusion of this parameter results in a firmly positive environmental impact in the U.S. instead of trade leading to a deterioration of the environment. Despite substantive growth, the pollution impact on Canada is zero. In Mexico, the trade impact remains negative. However, it is substantially reduced. If it were not for the special case of the petroleum sector, the trade agreement would lead to an overall environmental improvement. It can therefore be said that it is not possible to assume a firm link between trade liberalization and environmental degradation. On the contrary, insofar as wealth is a precondition for regulation setting, trade opening is likely to be an essential ingredient for achieving a clean environment. Furthermore, the impact of growth is more benign, the higher the regulation elasticity is. This means that from an environmental point of view the key leverage should be at supporting political institutions in poorer countries rather than in blocking trade.

Table 5-22. Analysis of different factors on their influence on modeling results

Factors	Explanation of simulation	Macroeconomic impact	Environmental impact	Remarks
1. Externality	Inclusion of a health externality, reducing also effective labor	Lowers effective labor supply; slightly lower growth	Small (less growth balanced by less stringent regulation)	Definition affects welfare assessment
2. Capital mobility	Allows capital to be mobile intra-NAFTA	Capital flows to MX, CN due to economic growth.	Relocates pollution across countries	Important for overall analysis
3. Importance of oil sector	All impact of oil sector on emission calculation is left out	None	Can revert sign for structural and overall effect	Sector is extremely important for overall analysis of pollution effect
4. Exclusion of petroleum sector from trade liberalization	Trade barriers for petroleum trade between Mexico and other countries remain in place	Reduction in NAFTA benefits; large changes in oil sector still occur due to intermediate demand expansion	Lesser impact of NAFTA, but no sign reversals	Mitigates overall effects, but results are qualitatively robust
5. Variation in externality	Use of toxicity index increases externality by 40%	Same as above	Same as above.	Results are robust, however, largely due to high weight of TSP.
6. Pollution indicators	Use of alternative indicators such as TSP, PM10, SO_2, NO_2, CO, VOC, and Toxicity	None	Possibility of sign reversal	Fairly robust results but net effect for individual pollutant is driven by fairly few sectors
7. Abatement elasticity	Lower elasticity makes pollution reduction more expensive	Lower growth as result of reduced costs	Practically unchanged	Negligible impact, but affects regulatory cost-benefit calculus
8. Abatement function	Labor enters abatement function next to capital	Alters incidence of regulation on labor and capital, and individual sectors.	Not systematic	No influence on aggregate values, but affects sectoral structure
9. Labor supply elasticity	Variation of labor supply elasticity from 0 to infinite	Higher labor supply elasticity increases GDP growth	Pollution increases, but scale effect is mitigated by stricter regulation	Can be neglected within realistic range of elasticity

continued

Table 22 (continued): Analysis of different factors on their influence on modeling results

Factors	Explanation of simulation	Macroeconomic impact	Environmental impact	Remarks
10. Demand elasticities	Reduction of demand elasticities	Reduces trade benefits (less than proportional)	Less total impact across the board; no sign reversals	Marked influence on magnitude of trade impact, but inconsequential for qualitative results
11. Economies of scale	Set scale elasticities to zero	Gains of trade specialization are diminished by a small amount	Slightly reduced scale effect	Practically no influence
12. Revenue recycling	Recycling of government revenues via labor taxes or transfers	Reduced labor taxes induce a tiny scale effect	None in practice	Can be neglected in case at hand.
13. Regulation elasticity	Income elasticity of regulation varies between 0 and 2	Higher elasticity reduces growth slightly; could be even positive in case of MX	The higher the elasticity the lower overall pollution.	Extremely important in overall pollution impact of trade liberalization
14. Policy function connected to wages	Instead of total income, wages determine regulatory stringency	Deviation of wages from income is not so great as to make a difference	Not systematic and very small	Can be ignored
15. Quantitative restrictions	Emissions are restricted by sector, instead of per unit of output	Sets higher restrictions for trade winners; slightly more balanced sectoral distribution of effects	Redefines structural emission effect	No noticeable impact on aggregate results; difficult interpretation of pollution change decomposition
16. Unilateral action	Increase in regulatory stringency by just one country	Reduced or unchanged growth in home country and trading partners	Large reductions possible in home country; pollution leakage minimal	Countries can set regulation unilaterally even in an open economy
17. Optimal sectoral regulation	Sets marginal abatement costs of all sectors equal	Lower abatement costs; higher growth and welfare gains; composition of economy moves towards less polluting sectors.	Knock-on effects beyond emission neutrality due to sectoral changes	Regulatory elasticity might increase as result of better regulation; however, this is not analyzed here

Second, regulations can be set independently of the trade regime. The simulations have shown that even when regulatory stringency is increased by 50 % unilaterally, there will be only small increases or even decreases in pollution in the trading partners. This does not change as a result of trade liberalization. It should be pointed out, however, that the model could only account for changes that are made on top of existing regulations. It cannot disprove that sensitive industries might have already migrated to pollution havens.

Third, good regulation setting can yield a double premium. Foremost, it frees resources through a better allocation of abatement expenditures and results in economic growth and increased welfare. Second, it improves the benefit-cost ratio of regulation of regulations, making stricter abatement more attractive. The most can be gained by the most regulated economies. The induced composition effect is ambivalent. It appears that the most polluting are at the same time the relatively most over regulated industries. However, this is subject to the caveat of statistical limitations. It does not emerge from the simulations that trade influences in any (significant) way the optimal structure of regulation, as the structural trade impacts are relatively small and unsystematic.

The final chapter will summarize the main findings of this paper and put them into the analytical context

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1. Research Question

6.1.1. Introduction

Much of the economic literature significantly misjudges the net impact of trade on the environment, because it takes sectoral emission factors as constant. However, this assumption conflicts with the common observation that wealthier countries apply stricter emission standards. The paper shows that the inclusion of an endogenous regulation-setting in the analysis substantially alters the environmental results of trade liberalization. The endogenous treatment of regulation-setting in a CGE model applied on a NAFTA data set indicates that in various simulations, stricter standards either reduce net pollution effects to a fraction of their uncorrected values or, in most cases, lead trade to reduce pollution levels. This outcome provides evidence to what can be formulated as institutional optimism in the trade and environment debate: pollution reduction from trade-induced institutional change compensates for the pollution increase caused by growth and compositionchanges that result from trade. Institutional change is a necessary condition for trade to have the effect of being environmentally beneficial. Policies to improve the environment in other countries should, therefore, focus on institution building rather than on trade.

The remainder of this section briefly recapitulates the literature on trade and environment and develops the theoretical base for the analysis. Section 2 describes the CGE model constructed. Section 3 defines the policy scenarios applied to the model. Section 4 focuses on the macroeconomic aspects of the simulations, while Section 5 traces the environmental consequences. Section 6 concludes.

6.1.2. Literature Review: Traditional Pessimism

Chapter 1 shows that the question of whether trade liberalization is harmful to the environment has generated a substantial body of empirical and theoretical literature (cf. surveys by Dean 1992; Beghin et al 1995; Ulph 1994). The theoretical and empirical literature has advanced in a number of ways. The discussion can be divided into two important empirical hypotheses: (1) the traditional pessimism and (2) the poverty attraction hypothesis. These are complemented by (3) the institutional optimism hypothesis developed in this paper.

The traditional pessimism hypothesis on trade and environment derived from a straightforward extension of the Heckscher-Ohlin model of comparative advantage:

Traditional pessimism hypothesis: differences in environmental regulations are an important factor in industrial location (industrial flight hypothesis). Since companies can avoid regulations by locating abroad, free trade erodes the independence of a country to set environmental policies and exerts a strong pressure towards lax regulation (pollution haven hypothesis).

A broad consensus has emerged in the literature that regulatory differences(with some exceptions) have, at best, a negligible impact on industrial location largely due to their small cost share. This result emerges both from studies looking at foreign direct investment (Leonard 1988; Xing and Kolstad 1996; Bouman 1996; Birdsall and Wheeler 1992) and trade flow analysis (Walter 1973 ; Kalt 1988; Jaffe et al. 1995; Robison 1988; Sorsa 1994; Low and Yeats 1992; Tobey 1990; van Beers and van den Bergh 1996, Scherp and Suardi 1997).[48] In its wake, the empirical consensus has substantially reduced the weight trade considerations have on regulation setting. There is also little evidence to suggest that countries (at least consciously) lure businesses with low environmental standards (Leonard 1988).

However, the consensus that regulation setting is not of great importance in industrial location still leaves the problem that trade between countries with vastly different regulations might have a quite damaging environmental impact. This is particularly important in the context of North-South trade, where economic specialization in polluting sectors can meet low environmental standards (Walter and Ugelow 1979; Copeland and Taylor 1994 1995; Chichilnisky 1994). A modified empirical hypothesis can be formulated.

Poverty attraction hypothesis: ***pollution-intensive sectors tend to be attracted to poor countries. Free trade leads to environmental degradation in poor countries, because the trade specialization is met with lax environmental regulation.***

The poverty attraction hypothesis differs from the traditional pessimism hypothesis in two aspects. First, while the traditional pessimism hypothesis applies also to countries with equal levels of development, the poverty attraction hypothesis expressly centers on countries at differing levels of economic development. Second, while regulatory differences drive the traditional pessimism hypothesis, this factor is incidental for the poverty attraction hypothesis. Specialization results from other factors such as relative capital endowments or differences in

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[48] However, the assembled evidence may be weakened by the fact that most studies rely on the

human capital. The evidence lends some support to environmentalist fears. A number of empirical studies confirm that developing countries tend to specialize in dirty industries (Hettige et al. 1992; Low and Yeats 1992; Birdsall and Wheeler 1992, Dessus and Bussolo 1998).

6.1.3. The Environmental Kuznets Curve

Another branch of empirical research hints that the relationship between a country's wealth and pollution follows an inverted U (Selden and Song 1994; World Bank 1992; Shafik 1994; Grossman and Krueger 1995; Lucas et al. 1992; Rock 1996)[49]. This phenomenon is known also as environmental Kuznets curve. It denotes the observation that the least developed countries have relatively low levels of toxic release, countries undergoing industrialization are highly polluted, and post-industrial countries are relatively clean. However, these findings are contested. Neither is it clear where the turning point might be located, nor does the absolute level of pollution decline in all cases (Esty and Gentry 1998). Furthermore, some resource degradation in early development phases might not be reversible.

A part of the observed environmental Kuznets curve can be explained by the typical economic development pattern. During an early development phase, a rising pollution level accompanies the economic specialization in the relatively dirty secondary sector. During a later development phase, a falling pollution level follows the growth of the relatively clean tertiary sector. This development results from the interaction of factor endowment with the structure of

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same data set compiled by the World Bank (Hettige et al. 1995) on which this study also draws.

[49] Lopez (1994) derives the result from a theoretical model.

demand. Poor countries tend to have a high demand for basic production, which tends to be dirty, both for final consumption goods, as well as for investment. Consumption in wealthier countries tends to be more directed towards durable, semi-durable and perishable goods and services. At first glance, this observation supports the poverty attraction hypothesis. However, this hypothesis alone cannot explain the reduction in pollution, because in practice dirty sectors shrinks only in relative but not in absolute terms.

6.1.4. Decomposition of Pollution

The mechanisms that could explain the downward sloping part of the environmental Kuznets curve can best be explained by disaggregating pollution causation into four components[50], all of which are affected by the trade regime (Figure 6-1).

Figure 6-1. Decomposition of Pollution Causation

$$Pollution = GDP * \frac{Production}{GDP} * \sum c_i * \frac{Pollution_i}{Production_i}$$

1. Scale — **2. Allocation Efficiency** — **3. Composition** — **4. Emission factor (Regulation)**

[50] Grossman and Krueger (1995) and the World Bank (1992) use a similar decomposition of pollution causation.

1. Scale effect: *ceteris paribus* pollution should increase in proportion to GDP. Beghin and Potier (1997) show in a survey that in many cases of trade liberalization the scale effect is substantially more important than induced changes in the economic composition.

2. Allocation effect: to the extent that GDP can be produced with fewer resources, the scale effect needs to be corrected downwards. Generally, this allocation effect (denoting increased factor efficiency) is driven by factor neutral technological progress.[51] However, in addition, trade liberalization affects this factor through (a) more efficient production patterns; (b) a welfare improving redistribution of output, even if production did not change at all (barter effect); and (c) the reduction in non-tariff barriers means that fewer resources are wasted in rent seeking, but increase are directed to net output.

3. Composition effect: the composition effect denominates the change in emissions that would take place if total output and technology stayed the same, and only sectoral shares changed. The composition effect of trade is at the heart of classical and the poverty attraction hypotheses.

4. Regulation (emission factor) effect: emissions per unit of output are affected by two factors. First, emissions could decrease as a result of non-neutral technological progress, which reduces the productivity of the environment as a sink for production wastes. Second, regulations reduce the amount of permissible emissions and force industries to employ pollution abatement technologies. The downward sloping Kuznets curve can only take place, if emissions per unit of output decrease during the course of economic development. The

necessity of a drop in emission factors points to a very important gap in the literature on the trade-environment link. It will be shown below that the omission of this effect substantially misjudges the net effect of trade liberalization on pollution.

6.1.5. Institutional Optimism Hypothesis

The unilateral focus of the literature on the demand side aspects of trade biases the analytical results because it takes factor endowments and institutions as constant. These assumptions result in an easy determinacy of the direction of trade-induced change: Trade is bad for environment, because it moves dirty industries to places where regulatory enforcement is weak (although the enforcement itself may not be the driver). However, as Chapter 2 argued, there is ample evidence that the trade-induced wealth should lead to a reduced pollution intensity per unit of output across the economy. Three causal chains can be identified that might contribute to institutional change.

First, pollution control requires the existence of functioning regulatory institutions. The existence of these institutions is intimately tied to a country's wealth, because the demand for environmental quality is highly income elastic.Clean environment is not simply a consumption amenity. It also reduces production costs due toreduced costs for clean-ups or its importance for health and, hence, productivity of the workforce. In certain high tech sectors, a clean environment even ranks as a precondition for attracting high skilled labor.

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[51] The World Bank (1992) calls this factor neutral technical change increased input-output efficiency.

The difference in institutional capacity between poor and rich countries is often remarked (Chichilnisky,1994; O'Connor 1994). Dasgupta et al. (1995) find empirically that the amount of regulation increases steadily with the growth of per capita incomes. A clear link can be established between the income and education level of the country and the level of public accountability of the administration (Hettige et al. 1996).[52] Therefore, at a conceptual level, a number of authors have argued that trade opening should be accompanied by institutional reform (Copeland 1996; Beghin et al. 1997; Runge 1994).

Second, it can be argued that trade itself, as opposed to autarky, increases the stock of knowledge by giving a country access to foreign innovations and knowledge (Grossman and Helpman 1995). Trade openness itself might therefore be associated with a cleaner industrial base (Birdsall and Wheeler 1992; Lucas et al. 1992). One component is that multinationals tend to apply similar standards to their operations globally (Pearson 1987; Warhurst and Isnor 1996, Levy 1995). However, the evidence on outward orientation and decreasing pollution-intensity has been questioned by Rock (1996).

Third, changes in the quality of factor endowments reinforce the trend toward lower emission intensities. In poor countries, capital stock is likely to be of old vintage and more polluting than newer equipment. Retrofitting is generally expensive. Therefore, environmental improvements are linked to the replacement of the capital stock. Low levels of capital endowment make environmental investments expensive in foregone production. Furthermore, a pool of unskilled labor gives a comparative advantage to traditional smokestack industries.

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[52] Selden and Song (1994) provide similar arguments.

However, the literature has largely ignored that environmental policy is endogenous to wealth creation. One exception is Bommer and Schulze (1996) who link regulation to labor income. A higher level of wealth can create the regulations that reduce the pollution resulting from the industrial expansion that accompanies trade. The importance of the trade-induced greening of production can be formulated as an alternative empirical hypothesis on trade and environment:

Institutional optimism hypothesis: *trade-induced wealth creates demand for stricter environmental regulations. This wealth effect on regulations can annul the pollution-increasing effects of trade-induced economic expansion and specialization in pollution-intensive sectors.*

Although the arguments for the institutional optimism hypothesis are not new, so far it has not been explicitly formulated or subjected to an empirical test. This paper fills the gap by applying a CGE model thattreats regulation setting as an endogenous function of wealth. The model allows testing the institutional optimismhypothesis by comparing the pollution-increasing effects of economic growth and trade specialization with the pollution-reducing effect of wealth creation. The hypothesis is applied to various trade policy scenarios among NAFTA participants, which serves as a microcosm of North-South trade relationships. It is shown that the perceived conflict between trade and environmental interests is largely the result of a misunderstanding in the full impact of trade openness. In many cases, the regulation effect is strong enough for trade liberalization to result in globally reduced pollution levels.

6.2. Model Description and Calibration

Thanks to their versatility, CGE models have been frequently used in the context of trade and environment interactions. These aspects are discussed in Chapter 3. However, no model has incorporated all of the three aspects that set pollution apart from other production factors. First, pollution depends not just on sectoral output, but on policies. This fact requires the inclusion of an abatement function in the model, as, for instance, in Dessus and Bussolo (1998) or Beghin et al. (1995), with an application to Mexico. Second, the economic evaluation requires the imputation of environmental externalities (e.g. provided by Ballard and Medema 1995; Copeland and Taylor 1995; and Smith and Espinoza 1996). Third, the assumption of constant regulations, and hence constant emission factors, needs to be relaxed (cf. Bommer and Schulze 1996).

6.2.1. Social Accounting Matrix

The model used in this paper is comparative-static and calibrated on the data contained in the Social Accounting Matrix (SAM) of Reinert et al. (1993). The SAM includes 26 sectors in the three NAFTA countries (USA, Canada, and Mexico) and is based on 1988 data. This means that any trade liberalization effects will also include the impact of the Canadian American Free Trade Agreement (CAFTA). The SAM does not include any information on environmental aspects of production. Notably, capital used in each sector needs to be split intocapital used for abatement and directly productive purposes.

6.2.2. Production

Producers areassumed to be profit maximizers. Production follows a nested constant elasticity of substitution (CES) structure. The top nest combines value added and intermediate goods. The model allows for economies of scale at this level. The intermediate aggregate is obtained by combining products in fixed proportion. Value added is decomposed into a labor and a capital component. Capital can be moved between sectors and employed for production itself and pollution abatement. It belongs to both domestic and foreign owners. The overall stock of capital in the economy is fixed. In the model, an increase in wealth is therefore not accompanied by a higher capital stock.

6.2.3. Households

Private demand is obtained by maximizing the nested utility function of a representative household. In the top nest, the household chooses between leisure and consumption. This function also determines labor supply. Labor supply is expressed in efficiency units,i.e. value added, not in hours worked. In addition to wages, households get revenues from government transfers and profits. Consumption e demand for individual products is the result of a CES function that combines the product of the individual sectors. Because the CES demand function has unitary income elasticities, the model does not capturewealth-induced changes in the structure of demand. Smith and Espinoza (1996) have analyzed this aspect, but their results suggest that these demand effects are relatively unimportant.

6.2.4. Government

The model includes a number of taxes, such as VAT, sales taxes, income taxes, capital taxes and customs duties. These revenues are used for transfers to households and the provision of public goods. The public good is a CES composite of various types of government consumption goods.

6.2.5. Trade

The model follows the standard Armington (1969) procedure of combining foreign and domestic goods to an aggregate, which can then be used for private or government consumption or as intermediate input. In parallel to imports, export supply is modeled as a constant elasticity of transformation function. The assumption that the balance of paymentalways remains the same as in the base year yields model closure.

Tariff rates are calculated from the SAM and are defined as actual collection rates. Additionally to tariffs, non-tariff barriers are included. Values are taken from Roland-Holst et al. (1993). It is assumed here that the value of the non-tariff barriers does not accrue to any economic actor as rent, but constitutes waste of economic resources used for rent-seeking. In the case of trade liberalization, the reduction in non-tariff barriers leads to an increase in resources for import consumption.

6.2.6. Emissions and Abatement

Physically, pollution is a joint output of production. However, in the production function, emissions are treated as input in addition to labor and capital, because higher permissible emissions reduce sectoral production costs. This is the standard approach of the trade and environment literature. For manufacturing, the sectoral emission factors per production unit of the model are derived from the International Pollution Projection System (IPPS) database (Hettige et al. 1995).[53] As is elaborated in Chapter 4, emission factorsfor non-manufacturing sectors are added from other sources (Jansen 1998). This paper concentrates on airemissions. Data are available for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), volatile organic compounds (VOC), carbon monoxide (CO), and total suspended particles (TSP). However, the

[53] The application of these intensities across countries is fraught with numerous methodological problems. There are even large variations within countries (Parjal and Wheeler 1995).

analysis focuses on TSP, since it is the most consistent pollution indicator for human health. Pollution from the process of consumption is omitted in the analysis, except for road transport.

Sectoral abatement data expenditures for the United States are derived from the Low (1992). This relationship is extrapolated to the other two countries. The assumption is that unit abatement costs and emissions in Canada are identical with those of the U.S. Mexico's abatement costs are assumed to be substantially lower (one sixth of the U.S. for all sectors), based on simple data inspection of U.S. and Mexican emissions inventories.

However, sectoral emissions and abatement factors can vary as a result of changes in regulatory stringency. Unit emissions factors depend on unit abatement expenditures through a simple constant-elasticity function. For each sector, an increase in baseline abatement expenditures by 1%, decreases unit emissions by 0.6%.

The emissions functions allow a representation of four important effects of trade on pollution. First, an increase in production is linked to an increase in emissions (scale effect). Second, emissions factors are based on production volume, not production value. The pollution factors per dollar of net output will drop (allocation effect), because, the simple barter effect of trade improves welfare without even when production does not change and, furthermore, less resources are spent on rent-seeking. Third, structural changes in the economy translate into emission changes (composition effect). Finally, through changes in the level of abatement, it is possible to reduce emissions per unit of output (regulation effect).

6.2.7. Externality

Environmental externalities are modeled in a very simplified way. Only the health effect of air pollution, or more precisely small particles, which are calculated from TSP emissions, is incorporated. Values for health effects are taken from the econometric data of Ostro (1987), which links air quality data to the number of sick days. This formula was applied to air quality data of the OECD(1995) and Romieu et al. (1990).

The approach translates emission changes into changes in labor output. In addition, the welfare function assumes a hedonic value of pollution of twice the lost output value to take account of suffering, sick days of non-workers, and early mortality. However, the externality figures are likely to underestimate the overall impact of pollution, as damages to crops and capital equipment and the impact of other associated pollutants are omitted. Sensitivity runs were used to analyze the impact of a toxicity-weighted aggregate of pollutants that increases the externality of particulates by roughly 40%.

6.2.8. Institutions

The permissible pollution and, consequently, the necessary pollution-abatement expenditures per unit of production are model-endogenous. The model solution algorithm determines them simultaneously with all other economic variables. Functionally, regulatory stringency is linked to changes in real disposable income and follows a constant elasticity function. Unfortunately, there is no literature that would support any particular value. The central case assumes that an increase in private consumption by 1% leads to 0.75% tighter emission standards per unit of output. The choice for a central value is based simply on plausibility considerations. If the value were one or larger, it would mean that, in practice, pollution would be unlikely to ever become a problem in any country over its whole development path. This conclusion cannot be squared with the empirical observation of the inverted U-shaped pollution curve.

By contrast, the model does not include any other emission reducing technology changes that might happen. However, in a comparative static model formulation, such a modernization effect takes the same form as regulation-induced abatement. The elasticity values could therefore even be interpreted to incorporate both factors.

6.3. Policy Scenarios and Baseline

6.3.1. Policy Scenarios

The analysis of the trade and environment complex that is discussed at length in Chapter 5 centers on four main policy scenarios around which also a number of sensitivity runs were undertaken.

Scenario 1:

The abolition of all NAFTA trade barriers assuming no transborder capital mobility. In the model, intra-NAFTA tariff rates are set to zero. All other tax rates as well as the overall provision of the public good remain constant. Changes in government revenues in the policy scenario translate into changes in transfers.

The reduction in non-tariff barriers is assumed to make formerly unproductive resource (used for rent-seeking) available as increased net output. The trade closure of this scenario assumes that exchange rates adjust to keep the balance of trade of each country at its pre-NAFTAlevel (measured in international currency). Capital cannot be transferred across countries.

Scenario 2:

The abolition of all NAFTA trade barriers assuming intra-NAFTA capital mobility. This scenario resembles the previous, except that it permits capital mobility within the NAFTA area. This mobility means that instead of leaving the balance of trade constant, the balance of payment (including capital transfers) remains at pre-NAFTA levels.

Scenario 3:

Trade liberalization with restrictions in the petroleum sector with and without assumed capital mobility (Scenarios 3a and 3b). Simulations leave all bilateral trade barriers between Mexico and the other two states for the petroleum sector intact, to examine its overriding importance for the Mexican economy as well as its high pollution intensity. To some extent, this scenario reflects the actual NAFTA treaty, where a number of restrictions for investment in the Mexican oil sector remain (cp. Hufbauer and Schott (1993, p. 33-36).

Scenario 4:

Unilateral increase in environmental stringency. As a direct test of importance of regulations on trade specialization, a set of simulations analyzes a unilateral reduction in unit emission for each country.

In addition to these main variants, a number of other sensitivity runs were undertaken. Variations in elasticities of demand, production, scale, labor supply, as well as different marginal costs of abatement were analyzed. These variations influence the order of magnitude of the trade effect in a predictable way,however, and do not change the qualitative picture of the results. Similarly, making abatement more expensive or introducing a substitution relationship between labor and emissions does not affect the results noticeably.

6.3.2. Dependence of Results on Pre-NAFTA Trade Barriers

The economic and environmental effects of the scenarios are substantially driven by the economic structure in 1988 before trade liberalization. To interpret the results, it is particularly noteworthy that pre-NAFTA trade barriers differ substantially across sectors. Predictably, most effects occur where barriers are highest. Since, the highest pre-NAFTA trade barriers tend to

be directed against primary and heavy industrial goods, there is a certain bias in the policy scenario towards a specialization in relatively polluting goods. This bias is less likely to exist if one wants to draw conclusions about trade in general. If pre-NAFTA trade barriers were the same for each sector, national factor endowments and production functions would be the exclusive drivers of the induced trade specialization.

Furthermore, the CGE model cannot analyze the impact of regulatory differences between countries as such, because of the equilibrium assumption. This is because sectoral profits are given in the SAM, a higher assumed abatement expenditure would only lead to a re-calibration such that the additional costs would be compensated by a higher productivity of the non-abatement capital. Therefore, the model can only analyze the impact of changes in abatement expenditures, not the impact of the existing absolute abatement levels.

Factor endowments are important for the economic specialization of the individual countries. However, factor endowments for production are not constant. The availability of the environment as a production factor can vary due to regulation. Effective production capital can be reduced by higher pollution abatement. Furthermore, labor supply depends on wage rates and income, as well as the health effect of changes in the pollution level. In addition, the production functions and, hence, economic efficiency in each sector vary among countries.

Finally, the welfare assessment of the NAFTA scenario deviates from the GDP figures. Welfare is based on three components. The first component, private consumption, is largely a leveraged GDP increase, because government consumption is fixed to its original level. The second component is leisure time, which is the inverse of the change in labor supply. The third component is the induced effect of NAFTA on health.

6.4 Macroeconomic Effects of Policy Scenarios

6.4.1. Scenario 1: Full Trade Liberalization with Immobile Capital

The abolition of trade barriers within North American has a positive impact on all three economies, causing total annual GDP to increase by $40 bn (1988 dollars) both for internationally mobile and immobile capital. In relative terms, the greatest winners are Mexico and Canada with GDP increases of more than 2%, while U.S. GDP increased by 0.6 % In absolute terms, however, two thirds of the benefits accrue to the U.S., a quarter to Canada, and only one tenth to Mexico.

The results are in line with the predictions of other models on NAFTA (e.g. models summarized in CBO 1993, Kehoe and Kehoe 1995, Brown 1994). However, a comparison is made difficult by the fact that not all other models have included the effect of CAFTA.

In the U.S. and Canada, capital rents rise slightly more than wages because of two factors. First, while the model assumes a constant capital stock, labor supply increases because of higher wage rates. This supply increase dampens the real wage increase. Second, the demand for abatement capital increases following the model-endogenous regulation tightening that results from the increased wealth. In Mexico, the gap between rents and wages is even larger, due to relative factor abundance. In terms of its production structure, Mexico is relatively labor scarce. The large number of workers in the country is more than balanced out by a low rate of labor productivity[54]. The results replicate the Stolper-Samuelson theorem that

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[54] This is only at first glance in contradiction to many other studies, which describe Mexico as a labor-abundant country. These studies use a definition based on work hours rather, while the present paper looks at the wage sum.

trade liberalization in a relatively capital-intensive country increases rents more than wages. In Canada and the U.S., this factor works in the opposite direction.

Sectoral effects of the scenario are also in line with the findings of other studies. Car manufacturing is expected to increase everywhere. Similarly, electronics increases, while textile and apparel growth is only moderate. Importantly, in the full liberalization scenario, petroleum production in Mexico increases substantially. This result is not universally present in other models, though some derive similar results (e.g. Brown et al. 1995, Sobarzo 1995). Since the petroleum sector is partly excluded from NAFTA, some authors have presented model simulations without this sector, others like in this paper have assumed that trade barriers in this area are also abolished. The consequences of this assumption will be discussed further below

6.4.2. Scenario 2: Full Trade Liberalization with Mobile Capital

The possibility of transferring capital from one country to another changes the nature of the trade closure. Capital is transferred to the country with the highest rate of return. In this the model, capital flows are exclusively driven by divergent developments in nominal interest rates. Since capital gains are relatively highest in Mexico, the country experiences a high inflow of capital from the U.S. This capital inflow leads to a substantially higher GDP growth (3.3% compared to 2.4% with immobile capital), and an even more substantial change in production volume (2.5% instead of 1.2%). Furthermore, it reinforces the industrial specialization of the country. Despite the higher GDP, private consumption in Mexico remains practically unchanged compared to Scenario 1, as the profits of the additional activity accrues to the United States.

Canada also experiences capital inflows from the U.S. However, they are insignificant. The changes on the U.S. side mirror those of Mexico, as GDP drops compared to the scenario with immobile capital. However, due to the large size of its economy, changes in the U.S. are relatively smaller, with GDP gains shrinking from 0.64% to 0.61%.

6.4.3. Scenario 3: Leaving out the Petroleum Sector

Unsurprisingly, the benefits of a NAFTA scenario that leaves out the petroleum sector are less than in the first two scenarios. There is a noticeable reduction in the trade benefits, mainly for Mexico but also for the U.S. In the case of immobile capital(Scenario 3a), Mexico's GDP gain drops from 2.4% to 1.9%, that of the U.S. from 0.64% to 0.59%. Canada remains practically unaffected, not least, because oil trade between Mexico and Canada is minimal. Nevertheless, the oil sector in Mexico still grows strongly by 6% instead of 14% driven by indirect demand. Owing to the capital intensity of the sector, the reduced welfare gains are borne slightly more by capital owners than workers.

For mobile capital (Scenario 3b), the effects of the scenario change even more dramatic for Mexico. Instead of a 3.3% GDP gain in Scenario 2, its economy increases only by 1.1%. This is notably due to a reversal in the flow of capital, which is now leaving the country causing accelerated growth in Canada and the United States instead. In this case, the oil sector even shrinks slightly.

6.4.4. Scenario 4: Unilateral Increase in Environmental Stringency

A unilateral decrease in permissible emission factors in the United States leads to a drop in GDP in the country by 2.3%. The incidence of the tighter regulations falls exclusively on wages (-4.75%), because effective labor supply increases by 0.3% due to a large improvement in health. By contrast, capital actually benefits due to the demand for abatement equipment and the increased labor supply (+3.16%). The U.S. economy therefore becomes more labor-intensive. The increased abatement costs therefore imply a structural change away from pollution intensive and capital intensive sectors.

One can notice some countervailing increase in the output of these sectors in the other two countries. However, Mexico and Canada do not sufficiently benefit from the reduced competitiveness of the U.S. in these sectors to compensate them for the decrease in GDP of their main trading partner. GDP shrinks by 0.3% both in Mexico and Canada. If the unilateral increase in stringency takes place in a setting with internationally mobile capital, the burden on these economies is substantially higher. GDP shrinks by 1.1% in Mexico and by 0.8% in Canada, because capital flows to the U.S. to profit from the increased return. This flow is accompanied by a reversal in the structural change. The secondary effect of connected capital markets causes structural changes to be in parallel with those of the United States. This change contrasts with the case of immobile capital, where structural changes in the other countries move in the opposite direction of those in the United States.

The case of unilateral action in Canada is directly comparable, given adjustments for its smaller size. So is the case of Mexico. GDP drops in all three countries. However, in the case of Mexico, low abatement costs and high externalities actually lead to loss in GDP that is an order of magnitude smaller than in the other two countries (0.2%).

6.5 Environmental Effects of Policy Scenarios

6.5.1. Scenario 1: Full Trade Liberalization with Immobile Capital

Pollution effects

Without tighter regulation, trade liberalization with immobile capital would simply lead to higher emissions in North America, if only because of economic growth. Due to the increased efficiency in the NAFTA area (allocation effect), the growth-induced pollution is less than the increase in GDP. Nevertheless, both effects combined would yield an increase in emissions in the U.S. of 0.2, in Mexico of 1.2%, and in Canada of 1.8%.

The compositioneffect modifies the results. In particular, Mexico shows a further increase in pollution of 2.2% because of economic specialization. This result means that its relative pollution-intensity is increasing. To a much smaller extent, Canada also experiences a small positive composition effect of 0.2%. By contrast, the value for the United States is negative. The country specializes in clean sectors. As such, this result gives support to the poverty attraction hypothesis, as the poorer country attracts the polluting industry.

Although the induced pollution specialization is not large, Mexico would notice a 3.3% higher pollution level were it not for a substantial 1.8% reduction due to tighter regulation that is induced by the increased income in the country. The inclusion of the regulation effect even leads overall emissions in the U.S. to drop by 0.6%, while those of Canada stay constant, despite the substantial economic growth and a slight specialization in pollution-intensive production.

Choice of alternative pollutants

The composition effect is robust to the choice of pollutants. Virtually an identical picture emerges for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), volatile organic compounds (VOC), and total suspended particles (TSP). The U.S. shows slightly negative values. Those for Mexico are strongly positive, while values for Canada are slightly positive. However, carbon monoxide (CO) and small particles (PM10) do not fit the picture. CO causes sign reversals for Canada and significantly lowers values for Mexico. PM10 even reverses signs for all countries. Some variation is to be expected simply because relative sectoral emission intensities vary by pollutant. This effect is reinforced by the dependence of the composition effect on only a few crucial sectors.

Welfare assessment

These induced changes in pollution are also evaluated in welfare terms. Simulations indicate that health (measured in changes in sick days) improves by 0.02% in the U.S. and deteriorates by 0.09% in Mexico, while it is virtually unchanged in Canada. Changing health levels affect welfare directly as one of its composite parts, and indirectly, because a lower number of sick days increases the effective labor supply. Better health therefore leads to a higher level of GDP. For the simulation reported here, these induced changes are small, but not completely negligible. They shift the total benefits of the trade agreement up by over 3% for the U.S., and down by more than 3% for Mexico. These figures are exclusively based on the externality of particles alone. If one also aggregates the effects of other air pollutants based on toxicity weights, the share of the externality in the overall welfare effect would be over 5% for both the U.S. and Mexico.

6.5.2. Scenario 2: Full Trade Liberalization with Mobile Capital

In scenario 2, which assumes full trade liberalization with internationally mobile capital, the capital inflow to Mexico substantially increases the pollution effect in the country. Both a higher absolute level of economic activity and a greater economic specialization drive up the pollution figures by more than 2%. However, the increased economic activity is not matched by a simultaneous increase in environmental stringency, because the benefits to of the capital inflow accrues to foreigners. This leaves private consumption, the driver of stricter regulations, practically unchanged.

By contrast, in the U.S. capital outflows reduce pollution levels, because economic changes in the U.S. are the reverse of those in Mexico. Here, the economy contracts slightly, and the country specializes more in low polluting activities compared to the scenario without international capital mobility. However, the relative changes are rather small.

In the case of mobile capital, the induced environmental externalities decrease Mexico's welfare gain by more than 8%. With a toxicity-weighted index, externalities would even reduce the trade gains by nearly 14%. For Mexico, the additional benefits of capital mobility in terms of higher GDP are outweighed by the welfare loss due to higher pollution. However, this cannot be seen as an indictment of trade liberalization as such, because the overall welfare gains are still solidly positive (+2.2%). The environmental damage from trade liberalization would have to be very substantial to overwhelm the welfare benefits in terms of higher economic growth.

6.5.3. Scenario 3: Leaving out the Petroleum Sector

In determining the overall pollution effect, the oil sector plays a crucial role – because of its high pollution-intensity and its importance, in particular for Mexican exports. Exempting the petroleum sector from trade liberalization implies for Mexico a lower scale effect a lower composition effect, and a reduced regulation effect. For immobile capital, the net impact on Mexico's pollution level remains only a third of the full liberalization case (+0.7%). However, no sign change occurs anywhere. Despite the restrictions on trade, the results are robust in this aspect, largely because the oil sector in Mexico still expands.

In the case of mobile capital, changes are more significant. The capital outflow leads Mexican emissions drop by more than 1%, instead of increasing by nearly 4%. The sharply reduced scale effect and a substantially reduced composition effect (3% less) dominate this change. By contrast, the net emissions reduction in the U.S. is less strong, while Canada's emissions even increase by 0.4%.

The scenarios therefore indicate that the resultsare sensitive to a single sector. This sensitivity can also be measured in the full trade liberalization scenario if emission changes due to the petroleum sectorare set to zero. This would substantially affect the composition effect. For Mexico, this modification would imply a net emission effect that is reduced by 1.8% in the case of immobile capital and 3.7% in the case of mobile capital. In taking out the effects of this one sector, environmental benefits are either strongly positive or insignificant, as the results are now dominated by the influence of tighter regulations.

6.5.4. Scenario 4: Unilateral Increase in Environmental Stringency

Simulating the unilateral increase in regulatory stringency in one country is the most direct test on the pollution haven hypothesis.[55] In the regulating country, the pollution reduction is noticeably higher than what would be expected by the regulation effect only. Next to the contracting GDP, the composition effect plays a substantial role, because as production moves away from abatement and pollution-intensive goods. In general most of this reflects actual changes in consumption. Relatively little of the composition effect is counterbalanced by concomitant increases in pollution-intensity in partner countries. Nevertheless, in the case of immobile capital trading partners experience an increase in pollution. This outcome is essentially the result of more lax regulations following a decreased private consumption.

The overall evaluation of a unilateral regulatory step depends, of course, on the magnitude of the GDP and health changes, which move in opposite directions. While health benefits substantially reduce the welfare costs of decreased output, in the U.S. and Canada and welfare decreases by 0.3, respectively 0.8%. By contrast, in Mexico a unilateral tightening of environmental stringency provides significant welfare gains of 1%. Health benefits are large, while GDP reductions are quite small in the first place, due to improved labor productivity and the low level of abatement expenditures.

As a variant of the calculating the effect of increasing environmental stringency unilaterally, one can derive for each country how large the regulation elasticity needs to be for

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[55] It is of no practical consequence whether this scenario is imposed on a benchmark with or without trade barriers in place. [56] This can be seen by transforming it into $U = (M^{\beta} H^{1-\beta})^{\gamma}$, where $\beta\gamma = 1$, and $(1-\beta)\gamma = \eta$. The allocation consequence of γ is zero, and could be left out.

trade liberalization to be environmentally beneficial. (Evidently, this value will differ by type of pollutant). In the case of the two scenarios with full NAFTA trade liberalization this threshold value would be very low for the U.S., at about 0.2; for Canada, the value is somewhat lower than 1. Mexico, by contrast, would need values between 1.5 and 2. However, there may be good reasons to believe that the elasticity in Mexico as a response to NAFTA is higher than in the other two countries due to institutional cooperation between the U.S. and Mexico (Runge 1994). The country appears under-regulated, and is subject to external and internal pressures to change this situation. Variations in the form of policy functions (e.g. by making it dependent on wages) do not influence these results notably.

6.6. Conclusions

Economic modeling in this paper shows that the incorporation of induced regulation-setting plays a crucial role in analyzing the environmental impact of trade liberalization. Under a broad range of trade liberalization scenarios in North America, the environmental situation improves not simply in general but also in each individual country. This occurs despite the fact that the pre-NAFTA structure of trade protection biases the result towards an expansion of pollution-intensive sectors. The, the net effect of the scenarios depends on a relatively limited number of factors. For NAFTA, changes in the petroleum sector are central.

However, the link between regulation setting and disposable income that is employed in the model must not be interpreted as being automatic and instantaneous. The functional form can at best represent a proxy for a complicated political process that hinges on a large number of factors. The responsiveness of institutions depends certainly on the degree of democracy in the country at hand. Furthermore, income distribution or, more generally, the distribution of political power will modify the link between aggregate wealth and regulation setting.

Nevertheless, contrary to much of the existing literature, the fully integrated pollution effects analysis demonstrated here points to a fundamental redirection in the trade and environment debate. In spite of differences in environmental stringency among countries, trade and environmental interests can be allies. Therefore, environmental concerns are best focused on transforming the institutions of the home country and that of the trading partners, not on restricting trade with institutionally weak countries. Consequently, the essential research question concerns the process that leads to institutional changes. This paper could only touch on this issue vaguely, and has to rely on a more or less plausible approximation.

Next to deriving empirical evidence to the country transformation hypothesis, the simulation results are consistent with conventional findings in the literature. First, they reproduce the consensus answer on the classical trade and environment question. Due to their relatively low cost impact, environmental policies matter only marginally in industrial location. The effect of stricter environmental regulations on trading partners depends crucially on the assumed level of capital mobility. Second, in line with the poverty attraction hypothesis, simulations show that within the NAFTA area dirty industry tends to move to the poorer country (Mexico). However, this conclusion depends strongly on developments in the oil sector. Third, the simulations show the importance of including externalities into the analysis. This inclusion leads to a noticeable revision in the overall welfare assessment of trade liberalization. Furthermore, it can be shown that for an under-regulated country like Mexico, a unilateral increase in regulations is possible that would allow for significant welfare improvements, even if sectors work in an internationally competitive environment.

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APPENDIX

CALCULATION ON OPTIMAL REGULATION-INCOME ELASTICITY

Let utility U be defined as a function of material well-being (M), and health (H), according to the following formula:

(i) $U = MH^{\eta}$.

The formula is an extended Cobb-Douglas formula, leaving the total share of health and material well being constant.[56] The model is simplified compared to the presentation in ETERNA, since it neglects that health has an impact on production itself via labor productivity. Under non-restrictive assumptions, such incorporation will not influence the basic proposition.[57] Furthermore, material well being is a function of production (P) minus abatement expenditure (A):

(ii) $M = P - A$.

Finally, the impact of abatement on health (H) follows the function

(iii) $H = \frac{1}{P}\left(\frac{A}{P}\right)^{\alpha}$.

This means that health improves with an elasticity of α, if the share of abatement expenditure in the economy increases, but worsens proportionally, if production increases. Utility can therefore be expressed as

(iv) $U = (P - A)P^{-\eta(1+\alpha)}A^{\alpha\eta}$.

The abatement expenditures is optimally set at:

(v) $A = \dfrac{\alpha\eta}{1+\alpha\eta}P$.

With the chosen utility form, the optimal adjustment path for a country as it gets richer would be to keep abatement expenditures at a constant ratio to overall income. This rate itself is higher, the bigger the externality (i.e. the higher α) is. A higher effectiveness of abatement expenditures (represented by a higher η) has an analogous effect. The formulation therefore would imply a unitary elasticity of pollution abatement expenditures with respect to income increases. This means that the regulatory elasticity of income would be zero. In other words, the level of pollution per unit of output would remain constant. Following equation (iii), pollution would increase as a result of growth. The reason for this lies in equation (i). In this formulation, both marginal costs and benefits increase in proportion to income, leaving the benefit cost ratio unchanged.

[57] It is only necessary to assume that material output follows a Cobb-Douglas function of labor and capital. In this case, the overall utility function could be presented in the same basic form as $U = MH^{\eta}$, except that η now includes both productive and hedonic effects of externality.