WHEN IS FREE TRADE GOOD FOR ENVIRONMENT?

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Abstract:

This paper explores the impact of trade liberalization on the quality of the environment, and provides the conditions under which free trade may reduce the emission of pollution. In this paper we construct a computable general equilibrium model based on the Antweiler, Copland and Taylor ("ACT", 2001) decomposition model of free trade and environment. Using data from different countries with different characteristics with respect to the stringency of their environmental policy and their factor endowment, we simulate a reduction in the import tariff and measure the variation in the scale, composition and technique effects of openness on the volume of emission.

Our main findings show that for a small, poor and open country (Brazil) with low endowment in capital, less stringent environmental policy, and high level of protectionism, if the country exports the polluting good, then trade liberalization creates opposite effects. A positive effect on the environment associated to the technique effect, and two negative effects scale and composition effects related to the increase in the production of the polluting good and the alternation of the domestic production towards more capital intensive production. The scale and the composition effects dominate the technique effect, and pollution increases. For a country with low endowment of capital, and quasi-stringent environmental policy, free trade may lead to a small reduction in the volume of emission if the technique effect dominates the scale and composition effects. For a rich country like Germany, with high endowment on capital, and highly stringent environmental policy, if the country exports the polluting good, then free trade leads to a decrease in the production of the polluting good, diversion of production factors toward the clean industry, reduction in the aggregated demand for the polluting good, more production and consumption of the clean commodity, and less emission. Finally, based on data from the United States, we conclude that trade liberalization in a country that exports the clean good and imports the polluting one, leads to a reduction in the production of the commodity that generates pollution, a reduction in the intensity of abatement and the tax on pollution, and an increase in the coefficient of emissions.

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Introduction

The relationship between Free trade and the environment has been the subject of extensive debates that were aimed to explore the impact of openness on the quality of the environment. From a theoretical angle, two theories seem to provide kind of explanation to this relationship. According to Copland and Taylor (2004), the pollution haven hypothesis ("PHH") constitutes a prediction under free trade, which stipulates that countries with relatively weak environmental regulation and low income will specialize in the production of the polluting goods. Multinational companies will reallocate their polluting industries to developing countries with less stringent environmental regulation. As a consequence of that, poor countries will become havens for polluters by exploiting their comparative advantage in pollution-intensive industries. Rich countries will benefit environmentally from free trade. While poor countries will become dirtier. The opposite of the PHH, is the factor endowment hypothesis ("FEH"). The latter predicts that, capital abundant countries will specialize in the production of the capital-intensive goods without any consideration given to the environmental policy. As a result, rich countries by exporting polluting goods get dirtier and countries that are relatively abundant in resources that are used in the production of the clean goods will become cleaner with free trade. Overall, the relationship between free trade and environment depends on the distribution of the comparatives advantages among countries.

The main purpose of this paper is to investigate empirically the impact of trade liberalization on the quality of the environment, by taking into consideration both the PHH and the FEH as determinants of a country's comparative advantage. First, we elaborate a computable general equilibrium model based on the Antweiler, Copland and Taylor (2001) decomposition model of free trade and environment, ("ACT" Model). The latter addresses the following question: "*Is free trade good for the environment*?" The originality of their results consists in showing that a trade liberalization which raises the Gross Domestic Product per person by 1% reduces the pollution by the same proportion via three channels: composition, scale and technological effects.[2] This statement is in

[2] For more details about the composition, technique and scale effects, see subsection 1.2.

contrast to many of the findings of environmentalists, who claim that economic growth and international trade constitute a threat to the environment.

Second, we identified four profiles of countries with respect to the PHH and FEH: a first type of countries with high capital endowment, and stringent environmental policy; a second group of countries with high capital endowment and less stringent environmental policy; a third type that includes countries with low capital endowment and stringent environmental policy, and finally a fourth kind of countries that are poor in term of capital endowment and less stringent in term of environment preservation. Based on this classification, we select four countries, for which we run simulations using computable general equilibrium models. These simulations consist of varying the import tariffs and measuring the variation on the volume of emission for each of the four countries chosen. It is also important to mention that the countries selected for the simulation possess different trade policies represented by different degree of protectionism.

Finally, we attempt to provide an empirical answer to the question when is free trade good for the environment. Our objective is to identify conditions, circumstances, and situations under which free trade may have positive impact on the quality of the environment. By using a static general equilibrium model in which the tax on pollution, the intensity of abatement, and the coefficient of emissions are kept endogenous to reflect the change in the perception of the quality of the environment impacted by trade liberalization, we conduct series of simulation to test the impact of import tariff reduction on the volume of emission through scale, technique and composition effects.

Our main findings show that, firstly, for a small, poor and open country (Brazil) with low endowment in capital, less stringent environmental policy, and high level of protectionism, if the country exports the polluting good, then trade liberalization creates opposite effects. A positive effect on the environment associated to the technique effect through a decrease in the coefficient of emissions; and two negative effects scale and composition effects associated to the increase in the production of the polluting good and the alternation of the domestic production towards more capital intensive production. The scale and the composition effects dominate the technique effect. Secondly, for a country with low endowment of capital, and quasi-stringent environmental policy, free trade may lead to a small reduction in the volume of emission if the technique effect dominates the scale and composition effects. Our simulations based on data from China, suggest that import tariff reduction may increase the aggregated demand for the polluting commodity. Consequently, the domestic production of such commodity may increase. Thirdly, in the case of a rich country like Germany, with high endowment of capital, and highly stringent environmental policy, if the country exports the polluting good, then free trade leads to a decrease in the production of the polluting good, diversion of production factors toward the clean industry, reduction in the aggregated demand for the polluting good, more production and consumption of the clean commodity, and less emission. Finally, based on data from the USA, we conclude that trade liberalization in a country that exports the clean good and imports the polluting good leads to a reduction in the production of the commodity that generates pollution, a reduction in the intensity of abatement, and the tax on pollution, and an increase in the coefficient of emissions.

The paper is organized as follows. A detailed study of the literature linking free trade and economic growth to the environment is presented in the first section of this paper. In the second section, I summarize ACT (2001) findings on free trade and environment. In Section 3, I develop a numerical version of the ACT model. The purpose of this model is to quantify the impact of trade liberalization on the quality of the environment. A computable general equilibrium model requires specific expressions for the production functions, the emission of pollution function, and for the consumers' preferences in terms of consumed goods and perceptions of the quality of the environment. In Section 4, I present the data and the calibration procedures. Section 5 presents the results and in Section 6, I provide some concluding remarks.

1. Literature Review

The complexity of the debate on free trade and environment and the necessity to link them to each other make many economists like Cooper (1994) and Bhagwati (1999) believe that it is better to keep pollution control and natural resource management issues out of the trade policy-making process. However for Runge (1994), Rodrik (1997) and

Summers (2000),[3] building a kind of environmental sensitivity into the international trading system is a better approach in order to analyze the link between environment and trade. The fundamental problem involves the role of trade on economic growth and the interaction between growth and the degradation of the quality of the environment. As put forward by Panayotou (2003), the crucial questions are:

"*Will the world be able to sustain economic growth indefinitely without running into resource constraints or despoiling the environment beyond repair? What is the relationship between a steady increase in incomes and environmental quality? Are there trade-offs between the goals of achieving high and sustainable rates of economic growth and attaining high standards of environmental quality?*" [4]

More specific questions have also been raised in the literature, such as: What are the effects of trade liberalization on environment and social welfare under the presence or absence of environmental policy? How do trade policy instruments affect environmental policies? How sensitive are open economies in terms of welfare and environmental protection to changes in environmental and trade policies abroad?

Anderson (1998) and Panayotou (1993) claim that an appropriate environmental policy would correct the price of resources. Resources are mis-priced by not taking into consideration the full amount of the social cost, which includes pollution. According to Stiglitz (2008), economic growth, which is based on environmental degradation and the exploitation of scare natural resources, cannot be sustainable if the proceeds have not been reinvested to compensate for the harm caused to the environment.[5] Free trade increases the volume of resources exchanged at prices that do not compensate for the harm to the environment. As stated by Esty (2001, page 113) *"…, the odds that increased trade will have net negative environmental impacts rise if resources are mispriced (Anderson, 1998; Panayotou, 1993). Around the world, many critical resources like*

[3] Quoted by Daniel C. Esty (2001), "Bridging the Trade-Environment Divide", The Journal of Economic Perspectives, Vol. 15, No. 3, page 113.
[4] Theodore Panayotou, (2003), "Economic growth and the environment", Paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva, page 1.
[5] Joseph E. Stiglitz, (2008), "Turn Left for Sustainable Growth", Economists' Voice, The Berkley Electronic Press, September 2008.

water, timber, oil, coal, fish and open space are underpriced (or overpriced) (World Bank, 1997; Earth Council, 1997)".

Nordstrom and Vaughan (1999) report that even the World Trade Organization acknowledges the negative effect of free trade on the quality of the environment (pollution harms and natural resource management mistakes) in the absence of appropriate environmental policy. By linking environment degradation and the scarcity of resources, Daly (1977), Georgescu-Roegen (1971), and Meadows et al. (1972), recommend a stop to economic growth and make a transition toward a steady state economy with no growth.[6] However, Barlett (1994) and Beckerman (1992) argue that the quality of the environment may become worse if the economic growth declines. In fact, they state that the surest way to improve the quality of the environment is by becoming rich.[7]

The World Commission on Environment and Development (1987) support the idea of sustainable economic growth. Many environmentalists continue to believe that economic growth can support environmental improvements if it is managed properly. However there are environmentalists who remain committed to "limits to growth" paradigm and found that trade liberalization increases economic activity, which leads to an accentuation of the pollution problem (see Meadows et al. (1972) and Daly (1993)).

Shafik and Bandyopadhyay (1992), Panayotou (1993), Grossman and Krueger (1993) and Selden and Song (1994) argue that the relationship between environment and economic growth may change sign from negative to positive as a country becomes rich and people demand more clean goods and high environmental quality. This relationship is similar to the famous "Kuznets curve" that links inequality of income and economic development. The development-environment relationship can be illustrated in the following figure: **[8]**

[6] Quoted by Panayotou, (2003), "Economic Growth and the Environment", Paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva, Page1.
[7] Quoted by Rothman (1998), "Environmental Kuznets Curves - Real Progress or Passing the Buck? A Case for Consumption - based approaches", Global Economics. , page 178.
[8] Source of figure 1: Theodore Panayotou, (2003), "Economic Growth and the Environment", Paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva, Page3.

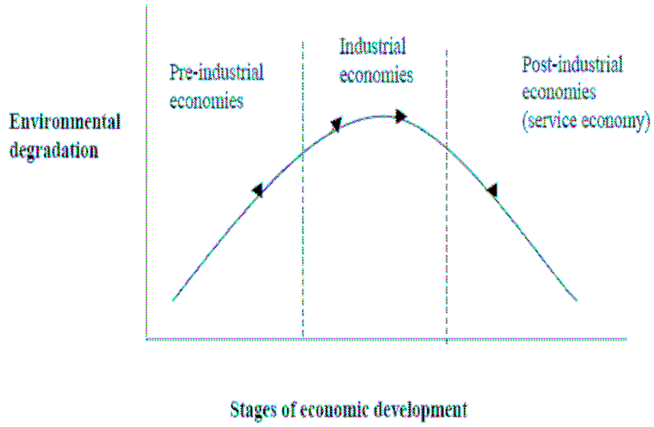

Figure 1: The Environmental Kuznets Curve: a development-environment relationship

The Kuznets curve shows that in the beginning of economic development, little attention is given to environmental concerns, raising pollution along with industrialization. Whereas, when basic physical needs are met, interest in a clean environment rises, reversing the trend. This curve has been widely used in the literature.

According to the World Bank's World Development Report *1992* (IBRD, 1992): *"The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments"* (p 38) and "*As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment"* (p 39).[9]

In the same trend Beckerman (1992, p 482) stated that: "*there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich.*"[10]

Quoted by Stern (2003),[11] Panayotou (1991, Page1) stated that: "*at higher level of development, structural change towards information-sensitive industries and services,*

[9] Quoted by David I. Stern (2003), "The Environmental Kuznets Curve", International Society for Ecological Economics, International Encyclopaedia of Ecological Economics, June 2003, Page 2.
[10] Ibid.
[11] Ibid.

coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation."

However the Environment Kuznets Curve (EKC) remains a subject of many critiques. Stern (2003) argues that the EKC has never been used with all pollutants or environmental effects. He argues that most of the theoretical model developed to show an inverted U shape curve of pollution intensity, come out with results that depend on the hypothesis made and the value of particular parameters.[12]

From a theoretical perspective, the EKC theory was the subject of many critiques. Arrow et al. (1995) and Stern et al. (1996) raise the possibility that the EKC may be "partly or largely" affected by trade and its impact on the distribution of polluting industries. In fact with trade liberalization, each country will specialize in the production in which it detains a comparative advantage. Such specialization may lead to a reduction in the degradation level of the environment in the developed countries and an increase in the environmental degradation level in "middle income" countries. These effects due to trade, according to Stern (2003), may accentuate the decline in pollution intensity as income rises.

From an empirical perspective, Beckerman (1992), Antle and Heiderbrink (1995), Chadhuri and Pfaf (1996), develop an empirical EKC model based on the role of income elasticity of demand for environmental quality to investigate the link between pollution and income. Boercherding and Deaton (1972), Bergstrom and Goodman (1973), and Walters (1975) found income elasticities for environmental improvements greater than one, while, Kriström (1995) found income elasticities for environmental quality much less than one. According to Stern (2003),[13] and Panayotou (2003),[14] most of the models

[12] Lopez (1994) and Selden and Song (1995) assume that pollution is generated by production. However John and Pecchenino (1994), John *et al*. (1995), and McConnell (1997) by developing an overlapping generations model, they state that pollution is generated by consumption. Also Stokey (1998) has developed a model with endogenous technical change. (Cited by Panayotou, 2003)

[13] Instead of using a simple quadratic function of the levels of income to estimate the EKC, by running the following regression: $\ln(E/P)_{it} = \alpha_i + \gamma_t + \beta_1 \ln(GDP/P)_{it} + \beta_2 (\ln(GDP/P))^2_{it} + \varepsilon_{it}$, where E is emissions and P is population [Ref: David I. Stern, (2003, page 4), "The Environmental Kuznets Curve", International Society for Ecological Economics, Internet Encyclopaedia of Ecological Economics] ; Stern found that an EKC estimated with fixed effects using only developed country data cannot be used to estimate efficiently

investigating the link between the environment and economic growth lack rigorous and systematic decomposition analysis that allows the decomposition of the income-environment relationship into composition, scale and abatement effects. Stern (2003) argues that, there are no clear answers on the effect of trade liberalization on pollution from the empirical EKC literature.

1.1 The Debate Free Trade/Environment

The arguments supporting the statement that free trade is good for the environment are as follows: Trade liberalization leads to economic growth. When countries become richer, households acquire more clean goods and polluters face a more restrictive environmental policy. Also trade liberalization implies a more efficient allocation of resources including environmental ones. It is also the best way to transfer environmental technology to developing countries. Free trade would permit the convergence to a high level of environmental standards for all countries, which would increase the market for clean goods all over the world. Finally, international trade may encourage international cooperation even in environmental issues.

The arguments against free trade underline the negative externality on the environment arising from the increase in economic growth. By promoting long distance transport, free trade accentuates pollution. Furthermore, since it is based on competition in both prices and costs, free trade may lead to what is called "Race to the bottom" behavior via competitive deregulation. Also, by promoting the production of the most traded goods rather than the set of commodities that would have been otherwise domestically produced and consumed, international trade accentuates the deterioration of the ecological equilibrium. This increases the degree of exploitation and the size of the land used to

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the future behaviour of developing countries. In fact Stern (2003), stated that "*…,the fixed effect can be estimated consistently, but the estimated parameters are conditional on the country, and time effects in the selected sample of data (Hsiao, 1986). Therefore, they cannot be used to extrapolate to other samples of data. This means that an EKC estimated with fixed effects using only developed country data might say little about the future behaviour of developing countries.*"

[14] A summary of empirical studies investigating the EKC theory is provided by Panayotou (2003), "Economic Growth and the Environment", Paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva, Page 44 (Appendix).

produce the traded products by exploiting lands for trade purposes instead of agricultural fins.

According to free trade theory, developing countries detain a comparative advantage in labour and natural resources. However, developed countries would specialize in manufactured capital-intensive activities. It is argued by Lucas *et al*. (1992) that, stringent environmental regulation in developed countries, might lead polluting activities to gravitate towards the developing countries.[15]

Panayotou (2003) states that as developed countries become richer, they may start getting rid of polluting industries through trade or direct investment delocalization in poorest countries with lower income and lower environmental standards. A new set of evidences coming from many recent researches shows that open economies tend to be cleaner than closed economies. In fact, according to Panayotou (2003), the best strategy to reduce the negative externality on the environment caused by the economic growth, is by removing environmentally harmful subsidies for example on energy and transport, by well define and enforce property rights, by a full cost pricing of resources to reflect the growing scarcities and by internalizing the environmental cost.

1.2 *The Decomposition Approach*

One way to further investigate the relationship between free trade and quality of the environment is by using an alternative approach based on the decomposition of emissions. According to Grossman and Kruger (1991) and ACT (2001), it is possible to decompose the effect of economic growth into "technique effect", "composition effect" and "scale effect". The "technique effect" means that when wealth increases and trade expands, firms become more willing to improve their technology and use what is called "environmental best practices". The composition effect reflects the shift in production toward cleaner or polluter goods.[16] Finally, the scale effect shows the increase in

[15] Quoted by David I. Stern (2003), "The Environmental Kuznets Curve", International Society for Ecological Economics, International Encyclopaedia of Ecological Economics, June 2003, Page 7.

[16] According to ACT (2001), the trade induced composition effect increases emission for an exporter of the polluting good and reduces the volume of pollution for an importer of dirty good. Grossman and Krueger (1991, page 4) argue that "*If competitive advantage derives largely from differences in environmental*

pollution due to more wealth consumption and expanded economic activity (Grossman and Krueger 1993; Lopez, 1994). To explain the impact of the free trade as a source of economic growth, on the quality of the environment, ACT (2001) show that above a certain level of wealth (per capita income), the technological effect becomes high enough to offset the summation of the scale and the composition effects,[17] in case of a dirtier good exporter.

De Bruyn (1997) uses the decomposition for sulphur emissions in the Netherlands and Western Germany. He found that between 1980 and 1990 the Gross Domestic Products grew by 26% for the Netherlands and 28% for Western Germany (Scale effect), and the structural change on the output side contributed (-4.5%) to emissions in Western Germany and (+5.7%) in the Netherlands (Composition effect). In the two countries, the technique effect contributed all together into a reduction of about 74% in sulphur emissions, that is; the energy efficiency by almost 15 to 20 % and the energy mix and emissions specific technological change by 55% to 60%.

Quoted by Stern (2003), Hilton and Levinson (1998) investigate the emission caused by gasoline consumption and conclude the existence of an EKC effect in 1992, by showing that the lead content per gallon of gasoline was a declining function of income and the per capita gasoline consumption is positively related to income. In fact, they infer the adoption by high-income countries of technological innovations. Stern (2002) also decomposes sulfur emissions in 64 countries for the period 1973-90 into what he identifies as "scale effect", "output mix" and "input mix" changes, and "state of technology", which can be divided into "production efficiency", and "emission specific changes in process". Stern concludes that the composition effect given by "output mix" and "input mix" effects globally have little impact. The technique effect known as "state of technology" seemed to reduce the increase in emission by 50%. Finally, ACT (2001)

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regulation, then the composition effect of trade liberalization will be damaging to the environment…. On the other hand, if the sources of international comparative advantage are the more traditional ones, namely cross-country differences in factor abundance and technology, then implications of the composition effect for the state of the environment are ambiguous".

[17] ACT (2001, page 886) states, "*For a dirty good exporter, both the trade-induced composition effect and the scale effect are positive*"

using the Global Environment Monitoring System ("GEMS") sulfur dioxide concentration data concludes that free trade is good for the environment.

According to Stern (2003), the new challenge facing researchers now consists of revisiting some of the issues addressed earlier in the EKC literature using the decomposition approach and rigorous panel data and time series statistics to provide rigorous answers to these questions, which are central to the debate on globalization and the environment.

In this paper, our contribution consists of developing a simulation model that will help to assess and quantify the impact of trade liberalization on the volume of emission using the ACT (2001) decomposition approach with respect to preferences and technological parameters. The investigation of the relationship between free trade and environment quality improvement using computable general equilibrium ("CGE") models will help us find a compromise across the different views expressed so far in the literature. Our main goal consists of identifying conditions under which free trade may lead to an improvement of the quality of the environment.

2. The ACT Model of Free Trade and Environment

The purpose of this section is to summarize the ACT Model and its main findings in order to develop a computable general equilibrium version of the model.

2.1 Description of the ACT (2001) Model

ACT (2001) develop a theoretical model using the decomposition approach as described in section 1.2. The model consists of a small open economy with two factors of production, labour and capital, which are used to produce two goods: X (polluting good) intensive in capital and Y (clean good) intensive in labour. The model also includes an abatement technology to reduce pollution. The intensity of emission is assumed to be negatively related to the amount of output x_a of the polluting good X invested in the abatement process. The polluting industry chooses the optimal level of abatement by taking into consideration the tax on pollution. This tax is endogenously determined by the social planner to optimize social welfare. The social welfare function is composed of the welfare of two groups of households with homogeneous preferences except for their perception of the quality of the environment. One group of consumers is called Green ("G") and prefers a clean environment. The other group is called Brown ("B") and is careless about the environment. The government manages the supply of pollution (volume of emission in the economy) through a tax on emission. Through the tax instrument the government sets endogenously the price for pollution. As the demand side of the volume of emission is generated by the polluting industry, the price of pollution ensures the equalization of demand and supply in the pollution market. It is important to note that ACT (2001) decompose the impacts of trade liberalization on the quality of the environment into scale, technique and composition effects.

Analytically, the producer problem consists of optimizing the following objective function taking into consideration the net of abatement price function:

$$\pi^x = p^N x - wL^x - rK^x \quad ; \; p^N = p(1-\theta) - \tau e(\theta)$$

p^N denotes the domestic price for the producer of the polluting good net of abatement and tax on emission; *x* represents the total volume of polluting good produced in the economy; *w* is the wage; L and K are respectively the demand for labour and capital to produce *x*; *r* is the rate of return on capital; *P* is the relative domestic price of good X; θ measures the intensity of abatement and is given by: $\theta = \frac{x_a}{x}$, where x_a refers to the quantity of *x* used for abatement. The term τ represents the rate of tax on emission; finally, $e(\theta)$ is the emission function.

Producers take as given the tax on pollution and find the optimal level of abatement that maximizes profit. The optimization procedure allows to express the emission coefficient as a function of the price and the tax on pollution. Indeed, by taking the derivative of P^N with respect to θ, the optimal level of abatement can be expressed as: $p = -\tau e'(\theta)$. $e(\theta)$ is assumed to be a decreasing function of θ. Since e'(.) is negative, the level of abatement θ is positively related to *p* and declines with the tax on emission.

The government maximizes a weighted sum of G and B consumers' preferences using the following expression of the indirect utility function V^i:

$$V^i(p, G/N, z) = u\left(\frac{G/N}{\rho(p)}\right) - \delta^i z \ ;$$

G is total income and N is the number of individuals in the economy. Consequently, G/N is per capita income; z is the emission of pollution; ρ(p) is a price index of the two consumed goods. Hence, the real per capita income ("I") is given by: $I = \frac{G/N}{\rho(p)}$; δ is the disutility coefficient of pollution. Note that $\delta^G > \delta^B \geq 0$. From a social welfare perspective, if the proportion of Green individuals in the economy gets larger, the environmental policy becomes more stringent with a higher tax on pollution. Since preferences over consumption are assumed to be homothetic, marginal utility with respect to income is declining. Consequently, an increase in the real income gives room for a higher τ and hence increases the demand for environmental quality. A higher tax on pollution given by a shifting up of the pollution supply curve makes pollution more costly.[18]

The indirect utility function can be transformed as: $V^i(p, G/N, z) = u(I) - \delta^i z$. To find the optimal tax on emission, the government solves the following optimization problem subject to private sector behaviour, production possibilities, fixed world price, and fixed trade friction.

$$\max_\tau N\{\lambda V^G + (1-\lambda)V^B\}$$

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[18] According to ACT (2001, page 882), the total income given by the summation of private sector net revenue "$R(p^N, K, L)$" and rebated taxes and expressed by: $G = R(p^N, K, L) + \tau z$, is a function of τ through two channels p^N and the last component of the expression of *G*. By assuming that world prices are fixed, ACT express the derivative of the real income per capita with respect to τ as: $\frac{dI}{d\tau} = \frac{\tau}{N\rho(p)} \frac{dz}{d\tau}$.

By taking the first order condition, the optimal tax on pollution can be given by the following amended Samuelson rule, which can be expressed as:

$$\tau = N[\lambda MD^{G}(p,I) + (1-\lambda)MD^{B}(p,I)]$$

$MD^{i}(p,I) = \delta^{i}\, \rho(p)/u' \;\; \forall i \in \{G;B\}$ is the marginal damage per person; λ is percentage of G customers in the population. One way to express this optimal level tax on pollution consists of using the following form: $\tau = T\phi(p,I)$ where $T = \lambda N\, \delta^{G} + (1\text{-}\lambda)N\, \delta^{B}$ defines the "country type" and $T\phi(p,I)$ is the effective marginal damage.[19]

2.2 Main findings of the ACT Model

According to ACT (2001), "*…if trade liberalization raises GDP per person by 1 percent, then pollution concentrations fall by about 1 percent. Free trade is good for the environment"*[20]

Also by distinguishing between the negative consequence of free trade on the quality of the environment in terms of the scale effect and the positive consequence in terms of the technique effect, they estimate that: *"…a 1 percent increase in the scale of economic activity raises pollution concentrations by 0.25 to 0.5 percent for an average country in our sample, but the accompanying increase in income drives concentrations down by 1.25–1.5 percent via a technique effect"*[21]

The composition effect implies that free trade alters the composition of the production in the national economy. Two hypotheses are confronted: the pollution haven hypothesis ("PHH")[22] and the factors endowment hypothesis ("FEH").[23] By conditioning trade effect

[19] Werner Antweiler, Brain R. Copland, and M. Scott Taylor, (2001), *"Is Free trade Good for the Environment?"* The American Review, September 2001, page 882.
[20] Werner Antweiler, Brain R. Copland, and M. Scott Taylor, (2001), *"Is Free trade Good for the Environment?"* The American Review, September 2001, page 878.
[21] Ibid.
[22] Copland and Taylor (2004) define the PHH as a prediction under free trade that stipulates that countries with relatively weak environmental regulation and low income will specialize in the production of the polluting goods. Multinational companies will reallocate their polluting industries to developing countries with less stringent environmental regulation. These poor countries will become havens for polluters by

on countries characteristics, ACT show that openness to free trade conditioned on country characteristics has a significant but small composition effect on pollution.

Moreover, the three effects are jointly estimated using data from 40 developed and developing countries. They make the distinction between types of pollution; one caused by income growth due to trade and the second one generated by capital accumulation or progress in technology. This distinction makes them conclude that, income gained from trade in a case of neutral technological progress reduces pollution. However, income gained from capital accumulation, which intensifies the production of the polluting goods, raises pollution. Therefore the effect of economic growth on the environment depends on the source of this growth.

According to ACT (2001), pollution concentration may rise in the first step due to capital accumulation before it falls through neutral technological progress. Also, trade patterns are determined by income and factor abundance differences. They develop a general equilibrium model of trade to examine the effect of a decrease in the trade barriers on pollution.

Under certain assumptions concerning the technology, the type of goods, and trade friction, and by taking into consideration a very specific kind of abatement policy, ACT (2001) *u*sed the decomposition approach into scale, emission and technological effects to formulate the following proposition: *"Consider two economies that differ only in their trade frictions: (i) if both countries export the polluting good, then pollution is higher in the country with lower trade frictions; (ii) if both import the polluting good, then pollution is lower in the country with lower trade frictions"*[24]

exploiting their comparative advantage in pollution-intensive industries. As a result, rich countries will benefit environmentally from free trade; wile poor countries will become dirtier.

[23] Considered by Copland and Taylor (2004) as an alternative to the PHH, FEH predicts that capital abundant countries will specialize in the production of the capital-intensive goods without any consideration given to the environmental policy. As a result, rich countries by exporting polluting goods get dirtier and countries that are relatively abundant in resources that are used in the production of the clean goods will become cleaner with free trade. Overall, the relationship between free trade and environment depends on the distribution of the comparatives advantages among countries.

[24] Werner Antweiler, Brain R. Copland, and M. Scott Taylor, (2001), *"Is Free trade Good for the Environment?"* The American Review, September 2001, page 884.

However this proposition, as ACT (2001) mentioned, captured a partial effect of trade liberalization through the composition effect. To see the full impact of a change in the trade friction on the quality of the environment, three effects: scale, income and composition effects, need to be assessed. As a result, they found that the technique effect offsets both the composition and the scale effects for an exporter of the dirty good.

By estimating the impact of trade liberalization on the environment, ACT (2001) find a positive and significant relationship between scale effect and concentration. Also, the technique effect is significant and reduces pollution. Openness to international trade for **an average** country reduces pollution under the assumption of constant endowments

3. Analytical Computable General Equilibrium Version of the ACT Model

In this section, I provide a detailed numerical version of the ACT Model. I start first by discussing the assumptions of the model, then present a detailed analysis of the producer and the consumer problem, and finally setup the equilibrium condition for the entire economy.

3.1 Assumptions and Structural Equations

Technology**:** We assume a small open economy made of N consumers and two industries "X1" and "X2", producing respectively two goods, x_1 and x_2, using two factors of production: labour (L) and capital (K). The industry X1 is intensive in capital and x_1 is considered a polluting good. The industry X2 is labour intensive and x_2 is considered a clean good in the economy. Both industries are characterized with a constant return to scale technology. The labor and capital markets are competitive, so that the wage and the rate of return on capital are freely determined by the interaction of supply and demand.

Interaction with the rest of the world: The small open economy keeps trade balance between exports and imports. We are in a Hecksher-Ohlin ("HO") world, so if the country exports the good x_1, it automatically imports the good x_2.[25] Let $P_i^*; P_i$ denote respectively the world and the domestic prices for the good x_i $\forall i \in \{1,2\}$. Consumers pay the world price for the exported good but imports are subject to a tariff rate "TM". The local price of the imported good is thus $P_i = (1+TM)P_i^*$. Tariff revenues are redistributed to consumers.

Production of the polluting good: The emission of pollution is generated by the production of good x_1. To compensate for the negative externality caused to the economy, the emission is taxed at τ^e. This tax is determined in an optimal way by maximizing a social welfare objective function subject to firm's effort to reduce its emission by investing in an abatement process, and the population preferences with respect to the quality of the environment. We assume that the industry X1 uses a part of its production to reduce its emission through a technology of abatement given by e(θ) where e(.) represents the coefficient of emissions.[26] This technology is function of the intensity of abatement $\theta = x_a / x_1$, where x_a is the proportion of x_1 used for the abatement.[27] For the coefficient of emissions, I take the same form as in ACT (2001) by assuming that e(θ) is a decreasing function of θ. However, for the general equilibrium model, I develop below an analytical expression for this coefficient of emissions, which I use to measure the volume of emission. Moreover, I need to determine the optimal level of abatement that maximizes the profit of the polluting industry. Evaluated at the world price, the value of the effort to reduce the emission of pollution is assumed to be given by $\theta x_1 P_1 *$. Also at the pricing level, the following expression expresses the domestic price of the polluting good in terms of world price: [28]

$$P_1 = \left[(1-\theta)P_1^* - \tau^e e(\theta) \right]$$

[25] There is no transfer of capital to or from the rest of the world to offset any variation in the trade balance.
[26] More details concerning the coefficient of emission are provided in the subsection bellow.
[27] ACT (2001, page 881) assume a constant abatement technology.
[28] This expression is given by equation (3) of the ACT Model (2001, page 881), which is appropriate for a small open economy.

The tax on pollution is endogenous in the ACT model to reflect the consumers' preferences in term of quality of the environment and it depends on the emission problem and the abatement effort by the polluting firm to reduce its pollution.

The emission of pollution: We define the emission of pollution by $z = e(\theta)x_1$, where z represents the volume of emission generated by production of x_1. It is positively related to both the coefficient of emissions e(.) and the volume of production of x_1. Besides, we assume that the coefficient of emissions is given by: $e(\theta) = 1 - \Lambda\theta^{\delta}$; $\delta \in \left]0,1\right[$ is a share parameter of the abated pollution.[29] If $\theta = 1$, the coefficient of emissions is given by $e(1) = 1 - \Lambda$. $(1-\Lambda)$ represents the amount of uncompressible emission. Since $e(1) > 0$, therefore $0 < \Lambda < 1$ is country specific. If $\theta = 0$, for each unit of good x_1 produced, the industry X1 generates one unit of pollution, and $z = x_1$.

Trade balance: The condition of balanced trade is given by $P_1^* TRD_1 + P_2^* TRD_2 = 0$, where TRD_i $\forall i \in \{1,2\}$ denotes the quantity of traded good x_i with the rest of the world, which can be expressed as $x_1(1-\theta) + TRD_1 = c_1$ for the polluting good and $x_2 + TRD_2 = c_2$ for the clean good.[30]

Structural equations: By assuming a Cobb-Douglas production technology, the production function for the industries X1 and X2 is given by:

- *For the polluting industry X1:* $x_1 = A_1 K_1^{\alpha} L_1^{1-\alpha}$; Where A_1 denotes the shift parameter and α represents the share parameter of the capital in the production of the polluting good. L_1 and K_1 denote respectively the labour and the capital demands by the industry X1.

[29] The volume of emission of pollution can be expressed as:

$$z = x_1 - \Lambda x_a^{\delta} x_1^{1-\delta} = x_1\left[\frac{x_1}{x_1} - \Lambda \frac{x_a^{\delta} x_1 x_1^{-\delta}}{x_1}\right] = x_1\left[1 - \Lambda\left(\frac{x_a}{x_1}\right)^{\delta}\right] = x_1\left[1 - \Lambda\theta^{\delta}\right] = x_1 e(\theta)$$

[30] c_i denotes the domestic consumption of good x_i $\forall i \in \{1,2\}$. TRD_i is positive if the country imports the commodity *i* and negative if the country exports that commodity

- *For the industry X2:* $x_2 = A_2 K_2^{\beta} L_2^{1-\beta}$; Where A_2 denotes the shift parameter and β represents the share parameter of the capital in the production of the clean good. L_2 and K_2 denote respectively the labour and the capital demands by the industry X2

Finally we assume a monotonic transformation of a constant elasticity of substitution ("CES") utility function, which can be expressed as follows:[31]

$$u(c_1, c_2) = \frac{\sigma c}{\sigma c - 1} \ln\left[\alpha c . c_1^{\sigma c - 1/\sigma c} + (1 - \alpha c) c_2^{\sigma c - 1/\sigma c} \right]$$

Where σ_c denotes the elasticity of substitution and α_c represents the share parameter of c_1 in the CES utility function.

[31] The utility function has to respect the assumption of homothetic preferences over consumption goods. A CES utility function is homogeneous of degree 1. The logarithm function ("ln") is monotonic. ln(CES) is a monotonic transformation of a homogeneous function of degree 1. ln(CES) is a homothetic function.

3.2 The ACT Model

3.2.1 The Producer Problem[32]

Domestic production of the polluting good: For a country that exports the polluting good, we can express the profit function facing the polluting industry X1 as:[33]

$$(1) \qquad \Pi^1 = x_1 P_1^* - c(x_1) - \theta x_1 P_1^* - \tau^e e(\theta) x_1$$

Where $c(x_1)$ represents the cost function for producing x_1, which is given by: $c(x_1) = wL_1 + rK_1$, that is, the sum of the cost of capital and labour. By the zero profit condition, equation (1) can be expressed as:

$$(2) \qquad x_1 P_1^* = c(x_1) + P_1^* \theta x_1 + \tau^e e(\theta) x_1$$

By manipulating equation (2), we can define the producer domestic price as a function of the world price:[34] [35]

$$(3) \qquad P_1 = \left[(1-\theta) P_1 * - \tau^e e(\theta) \right]$$

Based on this expression we can formulate the world price as: $P_1^* = \dfrac{P_1 + \tau^e e(\theta)}{(1-\theta)}$. From equation (3), the firm receives a domestic price below the world price ($P_1 < P_1^*$) as it is penalized for its emission of pollution through two channels: the abatement (θ) and the tax on emission $\tau^e e(\theta)$.

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[32] Table 2 in Appendix 5 summarizes the equations of the producers' problem. Appendix 5 is available upon request.

[33] If the country imports the polluting good, the profit function of the polluting industry can be expressed as: $\Pi^1 = x_1 P_1^* (1+TM) - c(x_1) - P_1^* (1+TM) \theta x_1 - \tau^e e(\theta) x_1$. This expression show that domestic producers of the polluting good benefit from a protection against foreign producers, given by the import tariff.

[34] For more detail see Appendix 1, which is available upon request.

[35] If the country imports the polluting good, the producer of the polluting good domestic price is given by: $P_1 = \left[(1+TM)(1-\theta) P_1^* - \tau^e e(\theta) \right]$

As $x_1\left[(1-\theta)P_1^* - \tau^e e(\theta)\right] = wL_1 + rK_1$, the domestic production for the polluting X1 sector can be formulated as $x_1 P_1 = wL_1 + rK_1$. Then by calculating the first-order condition with respect to x_1, the domestic price is found to be equal to the marginal cost: $P_1 = C_{x_1}(x_1)$; Where $C_x(x_1)$ is the marginal cost with respect to x_1.

To maximize its profit, the polluting industry in a country that exports the dirty good determines the optimal level of abatement, taking as given the tax on pollution. Its objective function to find the optimal level of θ subject to the tax on pollution can be expressed as follows:[36]

$$(4) \qquad \max_{\theta}(\Pi^1) = x_1 P_1^* - c(x_1) - P_1^* \theta x_1 - \tau^e e(\theta) x_1$$

Knowing that the coefficient of emissions is given by:

$$(5) \qquad e(\theta) = 1 - \Lambda\theta^{\delta}$$

By taking the first order condition with respect to θ, we get:

$$\frac{d\Pi^1}{d\theta} = 0 \Rightarrow -x_1 P_1^* - \tau^e x_1 \frac{de(\theta)}{d\theta} = 0 \Rightarrow -P_1^* + \tau^e \Lambda\delta\theta^{\delta-1} = 0 \Rightarrow \theta^{\alpha-1} = \frac{P_1^*}{\tau^e \Lambda\delta}$$

The optimal level of θ that maximizes the firm profit is given by:[37]

$$(6) \qquad \theta^* = \left(\frac{\tau^e \Lambda\delta}{P_1^*}\right)^{1/1-\delta}$$

Based on equation (6), the optimal level of abatement θ^* is positively related to the tax on pollution. Since $\frac{d\theta^*}{d\tau^e} > 0$, abatement increases as the tax on pollution raises.

[36] For a country that imports the polluting good, the objective function to find the optimal level of θ subject to the tax on pollution is given by: $\max_{\theta}(\Pi^1) = x_1 P_1^*(1+TM) - c(x_1) - P_1^*(1+TM)\theta x_1 - \tau^e e(\theta) x_1$

[37] For importer of the polluting good the optimal level of θ is given by: $\theta^* = \left(\frac{\tau^e \Lambda\delta}{P_1^*(1+TM)}\right)^{1/1-\delta}$

When maximizing its profit, X1 sets L_1 and K_1 as follow:

$$(7) \qquad L_1 = \frac{(1-\alpha)*P_1x_1}{w}$$; where w denotes the wage paid for labour

$$(8) \qquad K_1 = \frac{\alpha*P_1x_1}{r}$$; where r represents the rate of return on capital

Using equation (2) and the structural equation of the polluting industry, we can formulate the condition of null profit for the industry X1 as

$$(9) \qquad P_1A_1K_1^{\alpha}L_1^{1-\alpha} = w.K_1 + r.L_1$$

Domestic production of the clean good: In a country that exports the clean good, the profit function faced by industry X2 is given by[38]

$$(10) \qquad \Pi^2 = x_2P_2^* - c(x_2);$$

Where, $c(x_2)$ represents the cost function for the industry X2.

By analogy to the production of the polluting good, in order to maximize its profit, the industry X2 chooses the optimal levels of labour (L_2) and capital (K_2) such as:

$$(11) \qquad L_2 = \frac{(1-\beta)*P_2x_2}{w}$$; where w denotes the wage paid for labour

$$(12) \qquad K_2 = \frac{\beta*P_2x_2}{r}$$; where r represents the rate of return on capital

Concerning the price at the producer level for this commodity, since the problem of abatement and tax on emission do not apply to this industry, the price is given by:

$$(13) \qquad P_2 = P_2^*(1+TM),$$

[38] If a country imports the clean good, then the profit function of the industry X2 is given by:
$$\Pi^2 = x_2P_2^*(1+TM) - c(x_2)$$

Where $TM > 0$ if the good x_2 is imported from the rest of the world and TM = 0 if the good x_2 is exported to the rest of the world.

Using equation (10) and the structural equation of the clean industry, we can formulate the condition of null profit for the industry X2 as:

$$(14) \qquad P_2 A_2 K_2^{\beta} L_2^{1-\beta} = wK_2 + rL_2$$

3.2.2 The Domestic Consumption[39]

By maximizing their utility function with respect to their budget constraint, the consumers chose the optimal quantities of the domestic demands for x_1 and x_2 expressed by c_1 and c_2 respectively. The objective function is given by:

$$(15) \qquad u(c_1, c_2) = \left(\frac{\sigma c}{\sigma c - 1}\right) \ln\left[\alpha c . c_1^{\sigma c - 1/\sigma c} + (1 - \alpha c) c_2^{\sigma c - 1/\sigma c}\right]$$

$$\text{Subject to } PC_1 c_1 + PC_2 c_2 \le w\sum_1^2 LD_i + r\sum_1^2 K_i + \sum_1^2 (P_i^* .TM.TRD_i) + \tau^e e(\theta) x_1$$

Pc_1 is the consumption price of the polluting good; Pc_2 is the consumption price of the clean good; $w\sum_{i=1}^{2} LD_i$ is the total wage paid to consumers by both industries X1 and X2; $r\sum_{i=1}^{2} K_i$ is the total return on capital gained by consumers by lending their capital to both industries X1 and X2; $TRD_i \forall i \in \{1;2\}$ is the volume of imports of commodity *i*. $\sum_1^2 (P_i^* .TM.TRD_i)$ is the total tax on imports, which is simply redistributed to consumers; and finally $\tau^e e(\theta) x_1$ is the total amount of tax on emission from producing x_1 unit of polluting good, which is redistributed to consumers.

[39] Table 3 describes the main equations of the consumer problem. It is included in Appendix 5, which is available upon request.

By taking the first order condition with respect to the consumption of x_1 and x_2, we can express the domestic consumption as follows:

$$(16) \qquad \frac{c_2}{c_1} = \left[\frac{1-\alpha c}{\alpha c} \frac{PC_1}{PC_2} \right]^{\sigma c}$$

Using the equation (16) we can elaborate an expression for the share parameter αc which can be expressed as:

$$(17) \qquad \alpha c = 1 / \left[1 + \left(\frac{PC_2}{PC_1}\right) \left(\frac{c_2}{c_1} \right)^{1/\sigma c} \right]$$

Let R denoting the revenue of the household, we have:

$$(18) \qquad R = w \sum_1^2 LD_i + r \sum_1^2 K_i + \sum_{i=1}^2 P_i^* .TM.TRD_i + \tau^e e(\theta) x_1$$

By optimizing utility, household's revenue equals its consumption expenditure:

$$(19) \qquad R = PC_1 c_1 + PC_2 c_2$$

By solving the consumer problem analytically, we can express the optimal level of consumption form each commodity c1 and c2 as follows:[40]

$$(20) \qquad c_1 = R\alpha c^{\sigma c} / PC_1^{\sigma c} \{ PC_1^{1-\sigma c} \alpha c^{\sigma c} + PC_2^{1-\sigma c} (1-\alpha c)^{\sigma c} \}$$

$$(21) \qquad c_2 = R(1-\alpha c)^{\sigma c} / PC_2^{\sigma c} \{ PC_1^{1-\sigma c} \alpha c^{\sigma c} + PC_2^{1-\sigma c} (1-\alpha c)^{\sigma c} \}$$

Consumption price for the exported good is given by:

$$(22) \qquad PC_i = P_i^* \ \forall i \in \{1, 2\}$$

[40] For more details see Appendix 2.

Consumption price for the imported good is given by:

$$(23) \qquad PC_i = P_i^*(1+TM) \ \ \forall i \in \{1,2\}$$

3.2.3 Equilibrium Conditions

The Trade Balance: c_1 and c_2 represent the aggregate demand for consumption. As mentioned in the previous section, we can express the volume of trade for each commodity as follow:

$$(24) \qquad TRD_1 = c_1 - x_1(1-\theta)$$

$$(25) \qquad TRD_2 = c_2 - x_2$$

A positive value of $TRD_i \ \forall i \in \{1,2\}$ is synonym to imports and a negative value means that the country exports the commodity i, $\forall i \in \{1,2\}$. In order to ensure the trade balance, the following condition needs to be verified:

$$(26) \qquad P_1^* TRD_1 + P_2^* TRD_2 = 0$$

Market Clearing: In order to build a computable general equilibrium model, and run simulation to test the impact of trade liberalization on the quality of the environment, we need to ensure that at least all minus one market are in equilibrium. Therefore, we need to ensure the following conditions:

(27) $K_1^d + K_2^d = K^s$, where K^s denotes the capital endowment in the economy

(28) $L_1^d + L_2^d = L^s$, where L^s denotes the capital endowment in the economy

These two conditions describe the equilibrium in both the labour and the capital markets. Both w and r are kept endogenous in the ACT Model to be determined in an optimal way by clearing these two markets (total demand = total supply in each market).

Moreover, the equilibrium between demand and supply for both commodities x_1 and x_2 need to be verified through the following conditions, by transforming equations (24) and (25):

$$(29) \quad x_1(1-\theta) = c_1 - TRD_1$$

$$(30) \quad x_2 = c_2 - TRD_2$$

4. Data and Calibration of the CGE Model

Used as a link to bridge our analytical framework to the empirical estimation of the ACT model, this Section is dedicated to the description of the data and the calibration of the parameters used in our simulations. As preliminary steps before testing the model, this section provides first, a brief discussion of the role of the social accounting matrix ("SAM") and how to apply it to specific countries. Second, for each country selected, we calibrate the parameters contained in table 4, using data available from the SAM. Finally, we elaborate an expression of the optimal tax on pollution.

4.1 The Social Accounting Matrix

By recording all the transactions that take place in one particular year in a specific economy, the SAM represents a picture of the economy at a specific period of time. Historically, the SAM was used at least since 1759 under a French appellation "Tableau économique" (Studenski, 1958; Stone's, 1986; Timothy, 1996). Over time, the SAM had known to come across a lot of evolution under the work of Kuznets (1937), Leontief (1941), Meade and Stone (1941), and Stone (1947). A complete set of double-entry national income accounts were born and adopted by the United Nations (1953-1968) under the name of System of National Accounts, which has currently a worldwide use.

Harberger (1962)[41] and Johansen (1960)[42] were among the first to develop a SAM in order to construct an applied general equilibrium model. Scarf (1967, 1973) also made important

[41] For the US to measure the incidence of corporate income tax
[42] For the Norway to study the economic growth

contributions in the literature by making a connection between empirical and theoretical research.[43] In the last 30 years a large number of researchers have extended the CGE model in many relevant applications (see for example Ginsburgh and Waelbroeck (1981); Jorgenson (1984); Scarf and Shoven (1984); Manne (1985); Srinivasan and Whalley (1986); Taylor (1990); Bergman, Jorgenson, and Zalai (1990); Don, van de Klundent, and van Sinderen (1991); Mercenier and Srinivasan (1994); Timothy, 1996; Mérette and Fougère (1998), Merette, Mercenier, Beausejour and Hsueh (2001); Dissou (2005)).

One of SAM's properties is that each column indicates expenditures and each row indicates income. An accounting matrix principle consists of equating each row and column for each agent and industry.[44] Using data from 43 developed and developing countries to estimate the impact of free trade on the environment, ACT (2001) provide estimates of scale, composition, and technique effects for an average country in their sample. Their estimations show that for an average country, the total impact of trade liberalization will be a reduction in the volume of emission. By linking their estimations to both the PHH and FEH, ACT (2001) argue that for a poor country (low income per capita) with low capital to labour ratio, the PHH predicts that this country will be made dirtier with free trade. But in the same time the FEH stipulates that due to the lack of capital (in poor country), which is used in the production of the polluting good, the cost/price of capital becomes higher and the country produce less polluting good and more labour intensive commodity. It seems that the FEH is offsetting the impact of the PHH. Knowing that the impact of free trade on the volume of emission is a function of country characteristics, ACT find that certain country may benefit from a reduction in trade friction, when others are made dirtier.

In this paper, we used both the PHH and FEH to create four different country profiles with respect to their endowment on capital (capital to labor ratio "K/L") and the stringency of their environmental policy. To distinguish between countries with stringent environmental policy from those with less stringent policy, we use the effort of abatement as a reflection of their willingness to improve their environment. To do so, countries' polluting industry has to invest part of its production to improve its production techniques and reduce pollution. However, in countries that value less the environment, the polluting industry is less willing to

[43] Arrow and Debreu (1954) and McKenzie (1951)
[44] An example of the SAM is available in Appendix 6, which is available upon request.

incur the cost of abating pollution. Concerning the FEH, we use the capital to labor ratio to distinguish between country with low endowment of capital (low capital to labour ratio) and country with high endowment of capital.

These four profiles are used to identify four countries with different characteristics with respect to the PHH and the FEH. Moreover, since we assumed that each country cannot export and import the same commodity, and that the trade balance is in equilibrium according to equation (26),[45] the four countries are selected in such a way that we have countries that export the clean good and others that exports the polluting good. Besides, different degrees of protectionism are used among the four countries.[46] Concerning the volume of emission, the four countries are selected based on their Carbon Dioxide Emissions between 1990 and 2004 according to the United Nation development Report 2007.[47] For each country we construct a SAM based on year 2004 aggregated data that respects the ACT assumptions. Therefore we assume that both primary and secondary sectors constitute the polluting industry as defined in the ACT Model and the tertiary sector represents the clean industry.[48] [49] In addition to these four profiles, our selection of the four countries is based on their differences in term of their participation in the international trade, their emission of pollution problem and its evolution over time, and their degree of protectionism.[50]

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[45] To determine the volume and the $value of the imports and exports for each countries, we use data provided by the World Trade Organization report titled "International Trade Statistics 2005", which is available at: www.wto.org

[46] For the import tariffs, we use average tariff provided by the World Trade Organization Report on Tariff Profiles available at:
http://www.wto.org/english/tratop_e/tariffs_e/tariff_profiles_2006_e/tariff_profiles_2006_e.pdf

[47] Data on Dioxide emissions were calculated based on data from CDIAC, Carbon Dioxide Information Analysis Center, 2007. The results are available at the following address:
www.allcountries.org/ranks/carbon_fotprints_emissions_of_countries_1990-2004.html

[48] Primary sector includes agriculture, forestry and fishing; Secondary sector represents manufacture industry; and tertiary sector is made of the service industry. To simplify the SAM, and follow ACT assumptions, we ignore the consumption of intermediary goods as factors, which are needed to produce the final goods. We only used capital and labour as the two production factors to produce x_1 and x_2.

[49] Table 6 in the Appendix 7 provides a summary description of the four countries profiles with respect to the PHH and FEH. Appendix 7 is available upon request.

[50] Table 7 provides a complete description of the four countries. It is available in Appendix 8, which is available upon request.

For each country, we construct a SAM similar to the one provided in table 5, by taking into consideration the assumptions of the ACT Model.[51] These SAMs are used in the section below to calibrate the parameters characterizing each country with respect to the producer and consumer problems, the coefficients of emission, and the tax on pollution at the benchmark situation.

4.2 Calibration

Once the SAMs are balanced, numerical values of the parameters reflecting the behaviours of consumers and producers need to be calibrated in order to reproduce the initial equilibrium reported in the SAM (Annabi, Cockburn and Decaluwe, 2003).[52]

To complete the information contained in the SAM, we use an econometric estimation found in the literature for the elasticity of substitution between the two goods, x_1 and x_2.[53] Based on this estimated value of the elasticity of substitution, we use the information contained in the SAM to calibrate the rest of the parameters.

The calibration of the ACT Model consists in finding values for the share and the shift parameters characterizing the two production functions, the share parameter of the CES utility function, the rate of tax on pollution and the coefficient of emissions.[54]

To calibrate the intensity of abatement given by θ^B, which is used as a measure of the degree of stringency of the environmental policy, we elaborate the following formula:

$\theta^B = \left(3 - \frac{\pi^p(i)/\pi^p(world)}{\pi^e(i)/\pi^e(world)}\right)*10$; Where $\pi^e(i)$ is the annual economic growth rate in "*i*",

and $\pi^e(.)$ is the annual pollution growth rate in "*i*", $\forall i, i \in \{USA, China, Brazil, Germany\}$.

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[51] The SAMs for the four countries are available in Appendix 4, which is available upon request.

[52] The calibration consists of determining the parameters describing the behaviors of different economic agents in such a way that we reproduce the information contained in the initial SAM.

[53] For our simulation we assume that the elasticity of substitution is equal to 1.5.

[54] Table 8 provides analytical expressions for the parameters that need to be calibrated. It is included in Appendix 9, which is available upon request.

The benchmark value of θ is used to calibrate the coefficient of uncompressible emissions given by Λ in the expression of the emission coefficient.[55] The calibrated expression of Λ is presented bellow:

$$(31) \qquad \Lambda = \frac{-a2 \pm \sqrt{(a2)^2 - 4a1a3}}{2a1}$$

Where $a1 = \alpha c(x)\theta^{\alpha}$; $a2 = \alpha P_1^*(1-\theta)z + P_1^*\theta z - \alpha c(x)$, and $a3 = -P_1^*\theta^{1-\alpha}z$

Finally concerning the parameter δ in the expression of the coefficient of emissions, for each country we used a range of values, which satisfy the condition $\Lambda \in \left]0,1\right[$.[56]

4.3 The Tax on Pollution: Is There Any Possible Analytical Solution?

To compensate for the negative externality caused to the economy, the polluting industry has to pay a tax on pollution which is a function of the coefficient of emissions. As stated in the previous section, the optimal tax on pollution is estimated endogenously in the ACT Model. To solve analytically the problem of the tax on pollution, we maximize the indirect utility function of the consumers to which we subtract a component representing the disutility caused to the consumers due to the emission of pollution. The disutility term is a function of the consumers' perception of the quality of the environment of the "Greens" who give a high value to the environment and of the "Browns" who are less sensitive to the quality of the environment.

Let λ denotes the proportion of the Greens in the population. Hence (1-λ) equals the proportion of the Browns. Also, let δ^g and δ^b denote the disutility coefficients respectively associated with the Greens and the Browns. Then we can express the indirect utility function for each consumer in the same way as in ACT (2001):

$$(32) \qquad V^i(p, I, Z) = u(I) - \delta^i z,$$

[55] The calibration mechanism of Λ is presented in Appendix 10, which is available upon request.
[56] Table 9 in Appendix 11, provides a summary of the calibration stage, by assigning specific values to each parameter in the ACT Model. The results of the calibration is available upon request.

Where $V^i \ \forall i \in \{Green, Brown\}$ is the indirect utility function. p is the price index for consumption. I is per capita income. Z is the emission of pollution from the production of the dirty good. Consumers take the pollution level Z as given. The function $u(.)$ is increasing and concave on income.

To find the optimal rate of tax on pollution, we have to solve the following optimization problem:

$$(33) \qquad \max_{\tau^e} N\{\lambda V^G + (1-\lambda)V^B\};$$

Therefore, we need first to find an expression for the indirect utility function. Then we have to determine the first order condition with respect to the rate of tax on emission. Using the previous assumptions related to the properties of the consumers' utility function, and substituting the equation (15), (20) and (21) to the equation (32), we have:

$$(34) \qquad V^i = (\sigma c / \sigma c - 1)\ln\left[\alpha c \left(c_1^*\right)^{\sigma c - 1/\sigma c} + (1-\alpha c)\left(c_2^*\right)^{\sigma c - 1/\sigma c}\right]$$

Where c_1^* and c_2^* represent the optimal levels of good x_1 and x_2 that maximize the consumer utility function. Then via a few manipulations, we can express the indirect utility function as:[57]

$$(35) \qquad V^i = Ln(R) + \frac{1}{\sigma c} Ln\left(\alpha c^{\sigma c} PC_1^{1-\sigma c} + (1-\alpha c)^{\sigma c} PC_2^{1-\sigma c}\right)$$

The optimal rate of tax on pollution is given by maximizing the following equation with respect to the rate of tax on pollution.

$$M\,\text{ax}_{\tau^e}\ SW = Ln(R) + \frac{1}{\sigma c} Ln\left(\alpha c^{\sigma c} PC_1^{1-\sigma c} + (1-\alpha c)^{\sigma c} PC_2^{1-\sigma c}\right) - Z\{\lambda \delta^G + (1-\lambda)\delta^B\};$$

Where:

[57] For more details on how the equation 34 is derived see Appendix 3, which is available upon request.

- $R = w\sum_{1}^{2} LD_i + r\sum_{1}^{2} K_i + \sum_{i=1}^{2} P_i^* .TM.TRD_i + P_1^* \tau^e e(\theta) x_1$
- $e(\theta) = 1 - \Lambda \theta^{\delta}$
- $z = e(\theta) x_1$

Knowing that firms will chose their optimal level of abatement taking into consideration the rate of tax on pollution as given, we can express the coefficient of emissions as:

$$e(\theta) = 1 - \Lambda\theta^{\delta} = 1 - \Lambda\left(\left(\frac{\tau^e \Lambda \delta}{P_1^*}\right)^{1/1-\delta}\right)^{\delta} = 1 - \Lambda\left(\frac{\tau^e \Lambda\delta}{P_1^*}\right)^{\delta/1-\delta} = 1 - \Lambda\left(\frac{\Lambda\delta}{P_1^*}\right)^{\delta/1-\delta}\left(\tau^e\right)^{\delta/1-\delta}$$

Besides, by taking the rate of tax on pollution as given to fix the optimal level of abatement by the polluting industry, the solution to the maximization problem can be expressed as follow:

$$\frac{dSW}{d\tau^e} = 0 \Rightarrow \frac{dSW}{d\tau^e} = \frac{dLn(R)}{d\tau^e} - \frac{dZ}{d\tau^e}\{\lambda\delta^G + (1-\lambda)\delta^B\} = 0$$

The optimal tax on pollution is given by the following expression:[58]

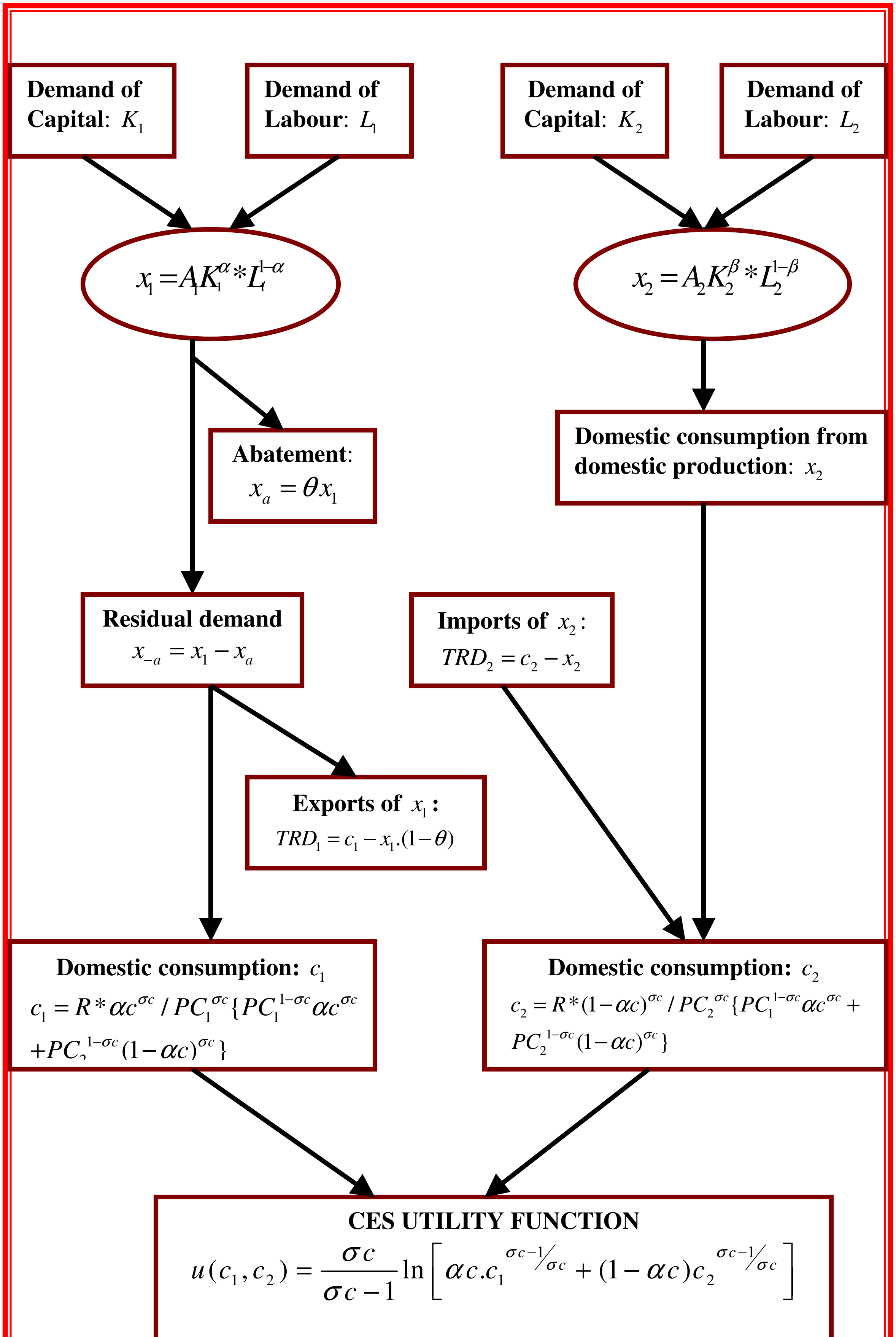
$$(36) \qquad e(\theta) + a\tau^e\left(\tau^e\right)^{\frac{2\delta-1}{1-\delta}} - a\left(\tau^e\right)^{\frac{2\delta-1}{1-\delta}} R\left[\lambda\delta^G + (1-\lambda)\delta^B\right] = 0$$

Where $a = -\frac{\delta}{1-\delta}\Lambda\left(\frac{\Lambda\delta}{P_1^*}\right)^{\frac{\delta}{1-\delta}}$

By using mathematical software such as GAMS,[59] an empirical solution to equation (36) is easy to find.

[58] Appendix 12 provides a detailed analysis about the calculation of the optimal tax on pollution. It is available upon request.

[59] GAMS stands for "*The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming and optimization. It consists of a language compiler and a stable of integrated high-performance solvers*" For more information see : www.gams.com


Demand of Capital: K_1
Demand of Labour: L_1
Demand of Capital: K_2
Demand of Labour: L_2
$x_1 = A_1 K_1^{\alpha} * L_1^{1-\alpha}$
$x_2 = A_2 K_2^{\beta} * L_2^{1-\beta}$
Abatement: $x_a = \theta x_1$
Domestic consumption from domestic production: x_2
Residual demand $x_{-a} = x_1 - x_a$
Imports of x_2: $TRD_2 = c_2 - x_2$
Exports of x_1: $TRD_1 = c_1 - x_1.(1-\theta)$
Domestic consumption: c_1
$c_1 = R * \alpha c^{\sigma c} / PC_1^{\sigma c}\{PC_1^{1-\sigma c}\alpha c^{\sigma c} + PC_2^{1-\sigma c}(1-\alpha c)^{\sigma c}\}$
Domestic consumption: c_2
$c_2 = R * (1-\alpha c)^{\sigma c} / PC_2^{\sigma c}\{PC_1^{1-\sigma c}\alpha c^{\sigma c} + PC_2^{1-\sigma c}(1-\alpha c)^{\sigma c}\}$
CES UTILITY FUNCTION
$u(c_1, c_2) = \frac{\sigma c}{\sigma c - 1} \ln\left[\alpha c . c_1^{\sigma c - 1/\sigma c} + (1-\alpha c) c_2^{\sigma c - 1/\sigma c}\right]$

5. Simulations and Main Findings

This section is dedicated to empirically test the impact of import tariff reduction on the volume of emission in the four countries selected in the previous section. Following the description of the ACT Model, and using the calibrated parameters provided in table 9, we first run simulations and measure variations associated to each variable of the model. Second, we provide analyses to explain the link between import tariff reduction and variation in the volume of emission. Finally, we summarize the conditions and circumstances to answer empirically the question: When is free trade good for the environment?

5.1 Simulations

The purpose of this subsection is to explore computationally the economic implication of a reduction in the import tariffs on the volume of emission in each of the four countries selected above. Note that the tax on pollution (Price/cost of the pollution) is endogenous in our model. This tax is simply based on a certain level of environment quality perception by the household,[60] which determines the stringency of the environmental policy as a function of the income level as suggested by Grossman and Krueger (1993) and Copland and Taylor (1994,1995) in their empirical work.[61] Considered as a pure bad public good, ACT (2001) argue that, if free trade leads to higher real income, which increases the demand for environmental quality, higher relative price of polluting good with respect to clean one or if greater weight is given to the Greens in the social welfare calculation, then we expect the rate of tax on pollution to increase as a result of trade liberalization.

In this paper we focus on the real income and relative price effects due to the complexity, and the ambiguity of assessing the composition of the economy in terms of Green and Brown and their respective disutility with respect to pollution.[62] In fact to assess the total

[60] Since we are using a static model of free trade and environment, the perception of the quality of the environment is assumed to be homogenous among households and reflected in tax on pollution.

[61] Grossman and Krueger (1993) and Copland and Taylor (1994,1995) highlight the importance of allowing environmental policy to change endogenously as function of change in the income level.

[62] We assume that consumers' perception of pollution is reflected in their optimal choice in term of consumed good by allocating their wealth between clean and polluting goods.

impact of trade liberalization on the quality of the environment, we can argue the following: From the demand for pollution side (producers of polluting good), if free trade leads to a higher tax on pollution, we expect producers of the polluting good to invest more in the abatement technology. As a result, the coefficient of emissions may fall. The total impact of a reduction on import tariffs on pollution will depend on the variation of the producer relative price between polluting and clean good.

For an exporter of the polluting good, trade liberalization is synonymous to a lower producer price associated to the clean good, since by assumption, domestic producers benefit from a protection against foreign industries given by the import tariffs (equation 13). However for the polluting good, trade liberalization affects producer domestic price through three channels: the intensity of abatement, the tax on pollution, and the coefficient of emissions (equation 3). Therefore, the impact of free trade on the composition of the domestic production will depend on the domestic relative producer price.[63] In a context where a county imports the polluting good, the producer's domestic price of the clean good remains invariant. However, the price of the polluting good will be affected, in addition to the intensity of abatement, the tax on pollution, and the coefficient of emissions effects, by the import tariffs. For this type of country, we expect that both scale and composition effects will lead to a reduction in the volume of emission, which is coherent with ACT (2001) findings.

By analogy to the trade induced composition effect, we expect that for an exporter of the capital intensive good, free trade increases the relative price of the polluting good and more resources are diverted to the production of such product. Also, abatement becomes more expensive and less attention is given to improve the emission technology. In the same time, because of the pure substitution effect of the goods price increase,[64] the tax on pollution increases. Overall, however, the increase in the tax on emission may not be

[63] According to ACT (2001), the magnitude of the change in the composition of output due to a decrease in the producer price of the polluting good caused by higher pollution tax depends on the importance of the pollution tax in the net price and the elasticity of the composition effect with respect to change in the producer price.

[64] Pure substitution effect take place when the world relative price of the polluting good increases in such a way that consumption of market goods becomes more expensive in comparison to environmental protection. The government intervenes by increasing the tax on pollution.

enough to offset the increase in pollution due to change in relative price and total emission from the composition effect increase. For an importer of the polluting good, free trade raises the relative price of the clean good and emission falls. The induced composition effect is expected to be positive for the exporter of the polluting good and negative for importer of this type of good.[65]

Concerning the scale and technique effects under free trade, we expect that for an exporter of the dirty good, the scale effect is positively related to volume of emission of pollution; however the technique effect, which determines the environmental policy response to the shock, is expected to be negatively related to volume of pollution. The total impact of free trade on emission will depend on the magnitude of the technique effect with respect to the scale and composition effect.[66] For an importer of the polluting good, the full effect of trade liberalization is expected to lower the volume of emission.

In assessing the role of factor endowments and the role of income differences to explain the impact of free trade on the quality of the environment, ACT (2001, page 887) argue that " *if the country is sufficiently capital abundant, it must export the capital intensive good.*" Also they state that *"if all countries have the same relative factors endowments, but differ in per capita incomes, then richer countries will have stricter pollution policy and this will lead to a comparative advantage in clean good.*" [67]

Based on the results obtained from the simulations,[68] for an exporter of the polluting good,[69] both the intensity of abatement and the optimal tax on pollution are positively related to the decrease in the import tariffs. However for a country that exports the clean

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[65] It is important to mention that the free trade induced composition effect does not take into consideration the impact of change in the trade friction on the scale of the economy and the income. Also it does not explain the determinant of trade patterns.
[66] According to ACT (2001, page 886), the full effect of free trade on polluting good exporter depends on the magnitude of the elasticity of marginal damage with respect to income. If the elasticity is below one than emission raises and it decreases if the elasticity is above one.
[67] Werner Antweiler, Brain R. Copland, and M. Scott Taylor, (2001), *"Is Free trade Good for the Environment?"* The American Review, September 2001, page 887.
[68] Table 10 describes the impact of tariff reduction on the coefficient of emission, the volume of pollution, the tax on pollution, and the intensity of abatement, which are determined endogenously in the model. The results are included in the appendix 13, which is available from the author upon request.
[69] Among the four countries we used to run simulations, China, Germany and Brazil are net exporter of the polluting good.

good,[70] both the intensity of abatement, and the tax on pollution vary in the same direction as the import tariffs. Besides, opposite results are found with respect to the coefficient of emissions, which varies in the same direction as the import tariffs when the country exports the polluting good and in the opposite direction if the country exports the clean good. The volume of emission seems to increase only in Brazil and decreases for the remaining countries. Brazil is the country with the lowest capital to labour ratio, the highest coefficient of emissions and the less stringent environmental policy.

In term of percentage of variation, the following table provides information on the magnitude of changes on coefficient of emissions, tax on pollution, volume of emission and intensity of abatement by comparing the situation post simulation to the benchmark state.

Table 11: Percentage of Variation Due to Tax on Imports Reduction

Brazil				
%	**Δ Coefficient of Emissions**	**Δ Volume of Emission**	**Δ Tax on Pollution**	**Δ θ**
TM*0.99	-0.11%	0.48%	0.40%	0.50%
TM*0.95	-0.57%	2.42%	2.01%	2.51%
TM*0.9	-1.13%	4.85%	4.02%	5.06%
TM*0.8	-2.24%	9.70%	8.10%	10.22%
TM*0.5	-5.44%	24.61%	20.54%	26.30%
TM*0.1	-9.36%	46.59%	37.20%	48.49%
Germany				
TM*0.99	-0.01%	-0.06%	0.01%	0.02%
TM*0.95	-0.05%	-0.30%	0.07%	0.08%
TM*0.9	-0.10%	-0.60%	0.13%	0.16%
TM*0.8	-0.21%	-1.21%	0.26%	0.33%
TM*0.5	-0.51%	-3.03%	0.65%	0.82%
TM*0.1	-0.93%	-5.47%	1.18%	1.48%
China				
TM*0.99	-0.01%	0.00%	0.02%	0.02%
TM*0.95	-0.04%	-0.01%	0.09%	0.12%
TM*0.9	-0.08%	-0.01%	0.19%	0.23%
TM*0.8	-0.16%	-0.02%	0.38%	0.47%
TM*0.5	-0.40%	-0.05%	0.94%	1.18%
TM*0.1	-0.72%	-0.08%	1.69%	2.12%
USA				
TM*0.99	0.00%	-0.01%	-0.04%	-0.01%

[70] USA is a country that exports the clean good among the four countries we used to run simulations.

TM*0.95	0.01%	-0.07%	-0.20%	-0.03%
TM*0.9	0.02%	-0.14%	-0.39%	-0.07%
TM*0.8	0.05%	-0.29%	-0.79%	-0.14%
TM*0.5	0.12%	-0.71%	-1.97%	-0.36%
TM*0.1	0.21%	-1.27%	-3.55%	-0.65%

Based on the information contained in this table, it appears that among the four countries, because of its high imports tariff at the benchmark situation, Brazil seems to be the most sensitive country to a reduction in the rate of tax on imports. For example, if the import tariff is cut by 20%, the volume of emission increases by 9.7% in Brazil, decreases by, 1.21% in Germany, 0.02% in China, and 0.71% in the USA.[71]

5.2 Main findings

Our main objective is to identify conditions and scenarios under which free trade can be a way to improve the quality of the environment. In this subsection we explore in detail the results of our simulations. For each country, we provide a separate analysis, and finally we conduct a comparative analysis between the four countries to assess when free trade is good for the environment.

5.2.1 Brazil

Brazil is a small country that exports the polluting good. Its capital to labour ratio is the lowest among the four countries selected for the simulation. It is also the country with the less stringent environmental policy and the highest import tariffs. In the Benchmark situation, Brazil uses 6% of its production of the polluting good to improve its technique of production. The cost of pollution is the lowest among the four countries considered, and its coefficient of emissions is the highest. When decreasing its import tariff by 1%, Brazil reduces its coefficient of emissions by 0.11%; its intensity of abatement increases by 0.5% and its tax on pollution by 0.4%. As a result, its emissions volume increases by 0.48%. The increase is also due to an increase in production of the polluting good by 0.6%. Even if the producers' prices for both commodities fall due to the reduction of the

[71] Table 12 provides a summary of the main results associated to the main variables which characterize the ACT Model. The table is included in Appendix 14, which is available upon request.

import tariff by 1%, in terms of relative producers' price, the latter increases by 0.08% in favour of the polluting product. Consequently, Brazil has incentive to produce more of the polluting good and less of the clean product. The following table provides details about the production, the relative price, the demand for capital and labour, and the relative factors prices for Brazil.

Table 13: Impact of Import Tariff Reduction on the Brazilian Industries

Percentage of variation		TM*0.99	TM*0.95	TM*0.9	TM*0.8	TM*0.5
Output	X_1	0.60%	3.01%	6.04%	12.21%	31.78%
	X_2	-0.81%	-4.05%	-8.15%	-16.56%	-43.70%
Capital Demand	X_1	0.52%	2.58%	5.16%	10.32%	25.92%
	X_2	-0.97%	-4.84%	-9.68%	-19.36%	-48.62%
Labour Demand	X_1	0.89%	4.54%	9.25%	19.25%	55.09%
	X_2	-0.60%	-3.03%	-6.17%	-12.84%	-36.73%
Relative Producer Price (p_1/ p_2)		51.50%	51.68%	51.90%	52.36%	53.89%
Relative Factors Prices (r/w)		100.38%	101.91%	103.89%	108.09%	123.16%

The table above shows that trade liberalization has a positive impact on the production volume of the polluting good (Scale effect)[72], and as well as a positive impact on the weight of the polluting good in total production (Composition effect).[73] However, a reduction in the import tariff reduces the coefficient of emissions (Technique effect)[74]. The total impact of trade liberalization on the volume of emissions seems to be more affected by the scale and the composition effects and less by the technique effect.

To produce more of x_1, which is intensive in capital, the demand for capital increases by 0.52% as a result of 1% reduction in the import tariff. In addition more labour is diverted to the production of the polluting good. In fact according to FEH, Brazil possesses high endowment in labour, therefore more additional labour (0.89%) than capital (0.52%) has been used to produce more of x_1. As a result of an increase in the demand for capital and

[72] As expected, free trade generates more activity and the production volume of the polluting good increases. If both the composition of the total output and the coefficient of emission remain constant, then we expect the volume of emissions to increase and more pollution to be generated.

[73] Free trade changes the composition of total output such that more of the polluting good is produced as compared to the clean good. This composition effect leads to more pollution generated in the economy.

[74] A reduction in the coefficient of emissions due to a reduction in the imports tariff constitutes an improvement in the abatement technology,which leads to less emission generated in the economy.

a decrease in the demand for labour by the clean industry in Brazil, there is an increase in the relative factors' prices.

From the consumers' perspective, trade liberalization leads to higher income, lower price for the clean good, and more consumption of both commodities. For example, a 10% decrease in the import tariff leads to an increase in the disposable income by around 1%. The consumption of the two commodities increases by 4.23% for the clean good and by 0.51% for the polluting good. The price of the clean good has decreased by 2.39%.[75]

The simulations conducted using data from Brazil - a small, poor and open country with low capital endowment, less stringent environmental policy, and high level of protectionism- show the following:

- If the country exports the polluting good, then trade liberalization creates two opposite effects: a positive effect on the environment associated to the technique effect through a decrease in the coefficient of emissions and a negative effect, due to the scale and composition effects, connected to the increase in the production of the polluting good and the switch of the domestic production towards more capital intensive goods.
- The scale and the composition effects dominate the technique effect. As a result of that, free trade leads to more pollution.
- The PHH dominates the FEH. In fact, the lack of stringent environmental policy seems to create more incentive for the polluting industry to produce and pollute more, in particular if the country exports the polluting good.
- Due to the HO trade assumption, by exporting the polluting good, trade liberalization seems to create more incentives for Brazil to produce for both the domestic and the international markets. For example, a 1% decrease in the import tariff leads to a 0.6% increase in the domestic production, which is accompanied by only a 0.1% increase in the domestic consumption.

[75] A summary of the consumers' reaction to tariff reduction in Brazil is provided in Table 14. It is included in Appendix 14, which is available upon request.

5.2.2 China

As an emerging–global economy, China exports the polluting good. With a low capital to labour ratio and moderate trade and environmental policies, China uses 22% of its production of the polluting good for abatement in the benchmark situation. Trade liberalization seems to have positive impact on the quality of the environment. For instance, a reduction in the import tariff by 5%, leads to a reduction in the volume of emissions by 0.01%. This improvement is due to a reduction in the emissions coefficient by 0.04%, an increase in the tax on pollution by 0.09% as well as a decline of 0.12% in the intensity of abatement. These results suggest that the technique effect is high enough to offset the impact of the scale and the composition effects combined.

Free trade leads to more production of the polluting good and to a decrease in the production of the clean product. The producers' relative price improves with trade liberalization. The same conclusion can be drawn with respect to the relative factor prices. Due to higher demand from the domestic and international markets for the polluting good, more resources are diverted to the industry X1, which is intensive in capital. Summary results for the Chinese industry reaction to trade liberalization are reported in the table below.

Table 15: Impact of Import Tariff Reduction on the Chinese Industries

	Output		Capital Demand		Labor Demand		Relative producer price	Relative Price of Factors
	x_1	x_2	x_1	x_2	x_1	x_2		
TM*0.99	0.01%	-0.04%	0.01%	-0.04%	0.01%	-0.03%	12.242%	100.01%
TM*0.95	0.03%	-0.20%	0.03%	-0.20%	0.07%	-0.16%	12.242%	100.04%
TM*0.9	0.07%	-0.39%	0.06%	-0.41%	0.15%	-0.33%	12.243%	100.08%
TM*0.8	0.14%	-0.79%	0.12%	-0.82%	0.29%	-0.65%	12.244%	100.17%
TM*0.5	0.35%	-2.00%	0.31%	-2.09%	0.75%	-1.66%	12.248%	100.43%

With respect to the Chinese consumers,[76] the result form the simulation suggest that trade liberalization in China, which leads to a lower price for the clean good, creates more incentive to consume more of the clean good and less of the polluting good. China's

[76] A summary of the consumers' reaction to a tariff reduction in China provided in Table 15. The table is included in Appendix 14, which is available upon request.

exports of the polluting good have increased with free trade. However, it is worth pointing out that, since taxes on pollution and on imports represent a source of revenue to the consumers and because trade liberalization leads to tougher environmental policy by diverting more resources to abate pollution, the adverse total impact of free trade on income is very small. For example, a 5% decrease in the import tariff reduces the disposable income by only 0.02%.

To conclude, we find that for a country with low endowment of capital, and quasi-stringent environmental policy, free trade may lead to a small reduction in the volume of emissions if the technique effect dominates the scale and composition effects. Our simulations based on data from China, suggest that an import tariff reduction may increase the aggregate demand for the polluting commodity, which includes both domestic and international markets. Consequently, the domestic production of such a commodity may increase. More resources are dedicated to the industry X1, and the production of the clean good decreases. The demand for both factors of production (labour and capital) increases for the polluting industry but decreases for the clean industry. As a result, the relative factor prices increases with trade liberalization. Moreover, it is important to mention that in absolute value, trade liberalization reduces producers' domestic prices, via three channels, the intensity of abatement, the coefficient of emissions and the tax on pollution. Such reduction may explain the decrease in the wage rate and the rate of return on capital.

5.2.3 Germany

Considered a rich country, with high capital endowment and a stringent environmental policy, among the four countries selected, Germany also exports the polluting good. With the highest intensity of abatement $(\theta = 0.335)$, Germany uses around 34% of its production of the polluting good to reduce pollution. As a consequence, its tax on pollution is the highest among the four countries examined. Moreover, Germany has the lowest coefficient of emissions in the benchmark situation.

Trade liberalization generates a small but positive effect on the quality of the environment. A 5% decrease in the import tariff reduces pollution by 0.3%. This is due, to a reduction in the coefficient of emissions by 0.05%, a reduction in the production of the polluting good by 0.25%, an increase in the tax on pollution by 0.07%, and an increase in the intensity of abatement by 0.08%. Free trade alters the structure of the German's industry towards the production of the clean good. The relative producers' price varies on favor of the clean good. Consequently, the demand for both capital, and labour increases for the clean industry, but decreases for the polluting industry. The Application of the decomposition approach shows that scale, composition and technique effects seem to contribute positively to the improvement of the quality of the environment in Germany. A detailed summary of the impact of trade liberalization on the industries in Germany is provided in the following table.

Table 17: Impact of Trade Liberalization on Producers in Germany

	Output		Capital Demand		Labor Demand		Relative producer price	Relative Price of Factors
	x_1	x_2	x_1	x_2	x_1	x_2		
TM*0.99	-0.05%	0.02%	-0.06%	0.02%	-0.05%	0.02%	12.718%	100.01%
TM*0.95	-0.25%	0.11%	-0.28%	0.09%	-0.25%	0.12%	12.718%	100.03%
TM*0.9	-0.50%	0.22%	-0.55%	0.18%	-0.49%	0.24%	12.718%	100.06%
TM*0.8	-1.01%	0.45%	-1.10%	0.36%	-0.98%	0.48%	12.717%	100.12%
TM*0.5	-2.53%	1.13%	-2.77%	0.90%	-2.48%	1.21%	12.715%	100.30%

Concerning the consumers, trade liberalization generates a small reduction in the income of about 0.26% if import tariff is reduced by 5%. This reduction can be explained by a decrease in the amount of tax on pollution collected, more resources diverted to abatement, less tax on imports, a reduction in the production of the polluting good, and mainly a reduction in wages and rate of return on capital caused by a reduction in the producers' prices. Besides, consumers benefit from a lower price for the clean commodity. As a result, the domestic consumption of the polluting good decreases and the consumption of the clean good increases.[77]

For a rich country with high endowment on capital, and highly stringent environmental policy, if the country exports the polluting good, then free trade leads to a decrease in the

[77] A summary of the consumers' reaction to tariff reduction in Germany is provided in Table 18. The table is included in Appendix 14, which is available upon request.

production of the polluting good, diversion of production factors toward the clean industry, reduction in the aggregated demand for the polluting good, which include both domestic and international markets, more production and consumption of the clean commodity, and less emission.

5.2.4 USA

USA is the only country that exports the clean good among the four countries selected. With a quasi-stringent environmental policy $(\theta = 0.22)$, more open to the rest of the world, USA seem to be benefiting from trade liberalization. For instance, a reduction in the import tariff by 5% reduces emission by 0.07%. According to ACT (2001), if a country imports the polluting good, all scale, composition and technique effects contribute to reduce the volume of emission. Our results suggest that, trade liberalization reduces the production of the polluting good and alters the domestic production towards more clean production. Whereas, less resources are dedicated to reduce abatement and the stringency of the environmental policy decreases. Both the intensity of abatement and the tax on pollution have decreased in a reaction to import tariff reduction. Consequently, the coefficient of emissions has increased. The overall effect of tariff reduction is a positive impact on the quality of the environment. The reduction in the production of the polluting good dominates the increase in the coefficient of emissions. The following table provides a detailed description about the impact of trade liberalization on the American producers.

Table 19: Impact of Tariff on Imports Reduction on the American Industries

	Output		Capital Demand		Labor Demand		Relative producer price	Relative Price of Factors
	x_1	x_2	x_1	x_2	x_1	x_2		
TM*0.99	-0.02%	0.00%	-0.02%	0.00%	-0.02%	0.00%	11.47%	100.00%
TM*0.95	-0.08%	0.02%	-0.08%	0.02%	-0.09%	0.02%	11.47%	100.00%
TM*0.9	-0.17%	0.03%	-0.16%	0.04%	-0.17%	0.03%	11.47%	99.99%
TM*0.8	-0.33%	0.07%	-0.32%	0.08%	-0.34%	0.06%	11.47%	99.98%
TM*0.5	-0.83%	0.17%	-0.81%	0.19%	-0.85%	0.15%	11.47%	99.96%

From the consumers' perspective, trade liberalization leads to a reduction in the consumption price of the polluting good, which creates more incentive to consume more of this good. In the same time, the consumption of the clean good decreases due to its high relative price with respect to the polluting good.[78]

Based on our main findings using USA data, we conclude that trade liberalization in a country that exports the clean good and imports the polluting one leads to a reduction in the output of the polluting industry, a reduction in the intensity of abatement and the tax on pollution, and an increase in the coefficient of emissions. The overall effect of a reduction in the import tariff is an improvement of the quality of the environment. Both scale and composition effects seem to have positive impact on the environment. However, the technique effect seems to be decreasing with free trade. Such decrease can be explained by the variation in the income.

6. Conclusion

In the context of a static general equilibrium model in which the tax on pollution, the intensity of abatement, and the coefficient of emissions are kept endogenous to reflect the change in the perception of the quality of the environment impacted by trade liberalization, we have attempted to create four country profiles, which we used to provide computational assessment of the effect of trade liberalization on the volume of emission. This paper investigates empirically, under which conditions and circumstances free trade is good for the environment.

We first explored the literature on trade, environment, and economic growth, trying to clarify the link between these three concepts. We faced different, opposing and sometimes ambiguous views and theories linking trade source of economic growth to the environment. Two theories have been explored: The Kuznets Curve Theory and the decomposition approach into scale, composition and technique effects developed by Grossman and Kruger (1993) and used by ACT (2001). The latter is summarized and then used as basic model to assess the impact of trade liberalization on the environment and to identify conditions under which such impact can be beneficial to the environment.

[78] A summary of the consumers' reaction to tariff reduction in USA is provided in Table 20. It is included in Appendix 14, which is available upon request.

We first solved the ACT Model analytically by assigning specific forms to the producer, and consumer problem, to the coefficient of emissions, to trade, and to the tax on pollution. Second we elaborate four different country profiles based on their characteristics with respect to their trade and environmental policies, their endowments and wealth, and their perception of the quality of the environment. Third, we select four countries with respect to these profiles. For each country we calibrate the parameter of the ACT Model. Fourth we conduct series of simulation to test the impact of import tariff reduction on the volume of emission.

Our main findings suggest that, for a small, poor and open country (Brazil) with low endowment in capital, less stringent environmental policy, and high level of protectionism, if the country exports the polluting good, then trade liberalization creates opposite effects. A positive effect on the environment associated to the technique effect through a decrease in the coefficient of emissions; and two negative effects scale and composition effects connected to the increase in the production of the polluting good and the alternation of the domestic production towards more capital intensive production. The scale and the composition effects dominate the technique effect. In fact, the lack of stringent environmental policy seems to create more incentive for the polluting industry to produce and pollute more.

For a country with low endowment of capital, and quasi-stringent environmental policy, free trade may lead to a small reduction in the volume of emission if the technique effect dominates the scale and composition effects. Our simulations based on data from China, suggest that import tariff reduction may increase the aggregated demand for the polluting commodity. Consequently, the domestic production of such commodity may increase. More resources are dedicated to the polluting industry, and the production of the clean good decreases.

For a rich country like Germany, with high endowment on capital, and highly stringent environmental policy, if the country exports the polluting good, then free trade leads to a decrease in the production of the polluting good, diversion of production factors toward the clean industry, reduction in the aggregated demand for the polluting good, which include both domestic and international markets, more production and consumption of the clean commodity, and less emission.

Finally, based on data from the USA, we conclude that trade liberalization in a country that exports the clean good and imports the polluting one leads to a reduction in the production of the commodity that generates pollution, a reduction in the intensity of abatement and the tax on pollution, and an increase in the coefficient of emissions. The overall effect of a reduction in the import tariff is an improvement of the quality of the environment. Both scale and composition effects seem to have positive impact on the environment. However, the technique effect seems to be decreasing with free trade.

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