Trade and Environment:

A Review of the Literature and A Computational Exercise

By

Xiao Huang

(3516626)

Major paper[1] presented to

the Department of Economics of the University of Ottawa

in partial fulfillment of the requirements of the M.A. Degree

Supervisor: Professor Marcel Mérette

Eco7997

Ottawa, Ontario

August 2005

[1] I would like to express my thanks to Professor Marcel Mérette for helpful guidance.

TABLE OF CONTENTS

1. Introduction

As the world economy develops increasingly, many issues such as global warming, white pollution, soil contamination and water scarcity come into the eyes of the people. Since the late of the 1970's, the environmental economic literature is burgeoning and a lot of researchers are concerned about the link between environmental quality and international trade. There exist two hypotheses that describe the relationship between international trade and environment. One is the *pollution haven hypothesis* and the other is the *factor endowment hypothesis*. The former suggests that the relative low-income countries will be made dirtier and the relative high-income countries will be cleaner if trade is liberalized. Following this hypothesis, the Kuznets Curve, which is an inversed U-shaped curve, depicts the relationship between pollution level and income of an economy, as illustrated in Figure 1.

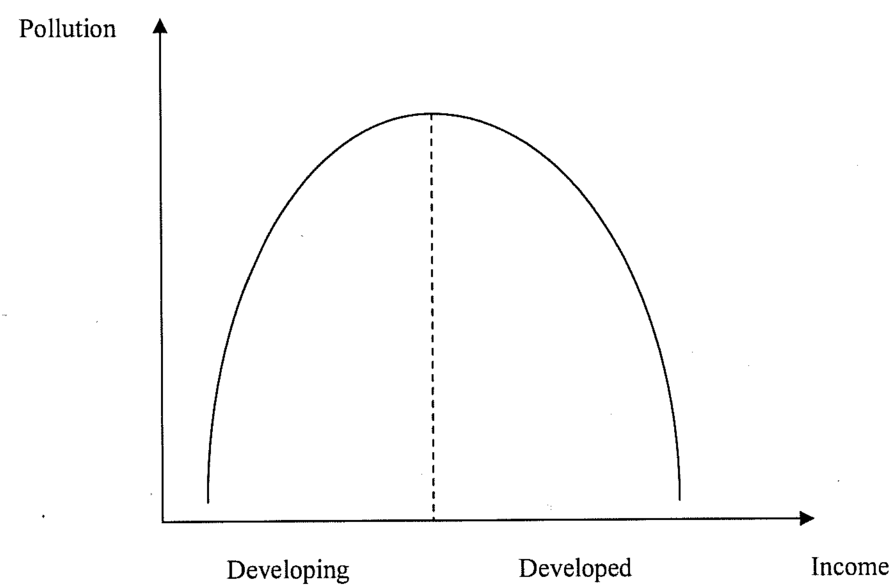


Figure 1: Kuznets Curve

The above figure implies that at the beginning of development, pollution increases. After a certain level of income, further economic development reduces pollution.

With the *factor endowment hypothesis*, pollution level is related not only to an economy's income but also to its factor endowment. As we know, an economy tends to export comparatively advantageous goods. For example, capital abundant countries export capital-intensive goods. From this hypothesis, comparative advantage is primarily a function of relative factor abundance and relative incomes. So we can divide trade's impact on environment into scale, technique, and composition effects. The so-called scale effect is that trade liberalization can improve a country's economy, but to some extent, by deteriorating the country's environment. On the other hand, as the country develops, the richer economy will be more able to improve techniques to protect the environment or to recycle environmental damages. This is defined as technique effect. International trade can also change the composition of goods exported and imported. If comparatively advantageous goods are polluting, then trade liberalization can lead to more pollution of production country. This is called the composition effect.

In this paper, we use a numerical model to analyze further an important proposition developed by Antweiler, Copeland and Taylor (2001) and suggesting that trade friction affects exportation or importation, eventually pollution. In their paper, the authors develop a theoretical framework to analyze the impact of freer trade on environment. The impact is decomposed into scale, technique and composition effects. The authors conclude that "if openness to international markets raises both output and income by 1 percent, pollution concentrations fall by approximately 1 percent"[2]. Our numerical model has three rather than two regions and hence permits a deeper analysis of the composition effect.

The remainder of this paper is organized as follows. In Section 2 we review the literatures on the link between trade and environment. In Section 3 we detail the theoretical model of Antweiler, Copeland and Taylor (2001). In section 4 we present our three-region numerical model. In section 5, we report some simulation experiments. In section 6, we conclude.

2. Literature Review

Is international trade good for environmental quality or not? How to get along with environmental quality, environmental policy and international trade? The relationship between environmental quality and international trade is the source of intense research for the last three decades. The points can be divided into three basic questions. That is: "How does economic growth affect the environment?"; "How do environmental regulations affect trade flows?" and "How has the pollution intensity of exports or production changed over time?"[3].

---

[2] Antweiler, Copeland and Taylor (2001): P. 903
[3] Idem, P. 879-880

Grossman and Krueger (1993) establish an important empirical relationship between air quality and economic growth, namely Environmental Kuznets Curve. To obtain it, they first estimate reduced-form regression models relating three air pollutants in a cross-section of urban areas located in 42 countries to the characteristic of the sites and cities where the pollution was being monitored and to the national incomes of these countries. They "find that for two pollutants (sulfur dioxide and "smoke") concentrations increase with per capita GDP at low levels of national income, but decrease with GDP growth at higher levels of income"[4]. They then construct a general equilibrium model to investigate the compositional effect of a North American Free Trade Agreement (NAFTA) on pollution in Mexico through studying the determinants of the industry pattern of the U.S.'s importation from Mexico and investigating whether the size of pollution abatement costs in the U.S.'s industry influences the pattern of international trade and investment. Their results suggest that: in poor countries, if the incomes are higher, environmental pollution will be higher; in rich countries, higher income will lead to a lower level of environmental pollution. These results are consistent with the *pollution haven hypothesis*.

Grossman and Krueger's (1993) paper has made two lasting and significant contributions. First, it helps to solve the question of "How does economic growth affect environment?". Second, it provides quite convincing evidence that there is an

[4] http://www.cepr.org/pubs/new-dps/dplist.asp?dpno=644

income effect associated with environmental quality. For instance, the paper suggests that weaker environmental policy helps to increase per-capita income.

Copeland and Taylor (1994) present a simple static two-country general equilibrium model to examine linkages between national income, pollution, and international trade. They first propose the definitions of the scale, the technique and the composition effects, and make their magnitudes related to tastes, techniques, and endowments. "The scale effect reflects the increase in pollution created by an increase in the level of economic activity in the relevant jurisdiction, holding constant the techniques of production and the composition of final output. The technique effect measures the change in aggregate pollution arising from a switch to less pollution-intensive pollution techniques, holding constant income and the range of goods produced. The composition effect measures the change in pollution due to a change in the range of goods produced by a country"[5]. They then use this decomposition to examine how pollution levels are affected by trade liberalization, scale-induced increases in income, and redistribution of world income. They show that "income gains arising from an opportunity to trade can affect environmental pollution in a different way from income gains obtained through economic growth and that economic growth has different effects on pollution in a free trade regime than in autarky"[6]. They find that economic growth in autarky has no effect on pollution levels since the technique effect can reduce pollution and the scale effect can increase

[5] Idem, P. 769-770
[6] Idem, P. 781

pollution, as a result, "the technique effect can fully offset the scale effect"[7]. However, international trade may lead to an increase in world pollution because of the composition effect. In addition, they also consider the interaction among environmental policy, economic growth and pollution. They show that if environmental policy is set optimally and imposes a cleaner method of production, then the potential increase in pollution generated by economic growth in autarky can be prevented. Moreover, "if differences in pollution taxes are the only motive for trade, and trade does not equalize factor prices, then a movement from autarky to free trade increases aggregate world pollution. Composition effects can also determine the impact of economic growth on pollution in free trade when growth is asymmetric across sectors. Even if, the pollution-generating effects of symmetric growth across countries are exactly offset by stricter environmental policy, the migration of industries induced by asymmetric growth has important and changing effects on pollution through the composition effect. Consequently, economic growth in the North has different effects on the environment than economic growth in the South"[8].

According to the above results, relative low-income countries have lax pollution policies and have a comparative advantage in dirty goods. Similarly, relative high-income countries have more stringent pollution policies and have a comparative advantage in clean goods. Once international trade occurs, the relative low-income countries will be made dirtier since they produce more and more dirty goods, and in

[7] Item, P. 782
[8] Copeland and Taylor (1994): P. 782

opposite, the relative high-income countries will be cleaner through international trade. This is consistent with the *pollution haven hypothesis*. Although this paper responds at least in part to the question of "How do environmental regulations affect trade flows?", it ignored the role factor abundance could play in determining trade patterns. Moreover, the paper does not measure the magnitude of each of the effects.

Grossman and Krueger (1995) examine a reduced-form relationship between per capita income and four different pollutants of local environmental conditions using panel data from the Global Environment Monitoring System. "The main contribution of this paper is that it employs the reliable data and a common methodology to investigate the relationship between the scale of the economy and the environmental quality for a broad set of environmental indicators"[9]. The authors find that there is no evidence to support the argument that economic growth necessarily harms environmental quality. Instead, in very poor countries, as GDP increases, the environmental conditions worsen, but once GDP reaches a certain level, the environmental quality improves. "The turning points vary for the different pollutants, but in most cases they occur at an income of less than $8000 (1985 dollars)"[10]. They also insist that "both the percentage of the population without access to safe water and the percentage of the urban population without adequate sanitation decline steadily at all levels of income"[11]. The improving of the environmental quality is not automatic and "the strongest link between national income and environmental pollution in fact is

[9] Grossman and Krueger (1995): P. 354
[10] Idem, P. 353
[11] Idem, P. 371

via an induced policy response"[12]. As nations or regions experience greater prosperity, their citizens demand higher living and working environmental conditions and the government that stand for the willing of their citizens will be pushed to pay more attention to the non-economic aspects. What is more, "it is possible that the downward sloping and inversed U-shaped patterns shift up because, as countries develop, they cease to produce certain pollution-intensive goods, and begin instead to import these goods from other countries with less restrictive environmental protection policies"[13].

Antweiler, Copeland and Taylor (2001) investigate how the environmental pollution will be affected by the extent of openness to trade opportunities. The authors contribute to the literature by empirically decomposing the total impact into scale, technique, and composition effects. They estimate the magnitudes of the three effects using a set of panel data on sulfur dioxide concentrations from the Global Environment Monitoring Project. Their results "consistently indicate that the scale, the technique, and the composition effects are not just theoretical constructs without empirical counterparts; rather, these theoretical constructs can be identified and their magnitudes can be measured. Moreover, once measured they can play a useful role in determining the likely environmental consequences of technological progress, capital accumulation, or increased trade"[14]. Greater trade leads to the increase of the national income and output. "These associated increases in output and incomes will then exert

---

[12] Idem, P. 372
[13] Grossman and Krueger (1995): P. 372
[14] Antweiler, Copeland and Taylor (2001): P. 902

an impact on pollution concentrations via their estimated scale and technique effects. Their final result is that if openness to international markets raises both output and income by 1 percent, pollution concentrations fall by approximately 1 percent"[15]. The eventually somewhat surprising result is that "freer trade is good for the environment"[16]. Notice, however, that the model the authors develop allows income and factor abundance differences to jointly determine trade patterns. Obviously, this paper may have a bias in favor of the *factor endowment hypothesis*.

Copeland, Brian and Taylor (2004) confirm that environmental quality improves as income increases. Although increase in national production sacrifices environmental quality, the induced development of the national income will then help to improve the environmental quality. There are a positive effect and a negative effect, but overall, the net effect is positive. The authors also do not agree with the point of view that environmental policy does not affect trade and investment flows. "A number of recent studies find that both trade and investment are influenced by pollution regulations and pollution abatement costs are dependent on industry attributes. Measures of trade performance (such as import penetration) and pollution abatement costs are both endogenous variables. Therefore, the common finding of a weak or nonexistent relationship between pollution abatement costs and import penetration is likely to be a symptom of economic problems and not evidence that environmental

[15] Antweiler, Copeland and Taylor (2001): P. 903
[16] Idem, P. 903

regulations are irrelevant"[17]. The conclusion of the paper is that "there is little convincing evidence to support the pollution-haven hypothesis. While there is evidence of a pollution haven effect, it is only one of many factors that determine trade patterns, and there is no evidence that it is the dominant factor"[18].

3. A Theoretical Model of Trade and Environment (Antweiler et al. (2001))

In this section, we present in details the model of Antweiler at al. (2001). In particular, we describe the various steps and manipulations of the equations presented in their paper. We then present their "***PROPOSITION 1***" that we will re-visit with our numerical model developed in the next section.

Preliminaries:

In this model, we suppose that there is a small open economy which has a population of N agents and which produces two kinds of goods, X and Y. There are two types of primary factors, labor L and capital K. X is a capital intensive good and does pollute. Y is a labor intensive good and does not pollute. The unit cost functions of goods X and Y are $c^x(w, r)$ and $c^y(w, r)$ respectively, where the return to labor is wage denoted by w and the return to capital is denoted by r ; The technology follows constant returns to scale. The price of good Y is assumed to be the numeraire. Hence

[17] Copeland and Taylor (2004): P. 66
[18] Copeland and Taylor (2004): P. 67

the relative price of X will be $p = \frac{p_x}{p_y}$.

Major Content:

As we know, trade barriers distort domestic prices with respect to international prices. For instance, the presence of tariff hinders the ability of importing and the domestic firms or consumers may have to pay more for imports of raw materials or consumer goods. In such a case we expect the domestic price to be higher than the world price: $p = (1+t)p^w$. Additionally, transportation costs may have the same effect on the price system as trade barriers. For example, let us denote transport cost by v, where v is the ratio of the amount of goods arriving at destination compared to the total amount produced. In this case, v is smaller than 1. If the good is imported, then $p = p^w/v$; if the good is exported from home, then $p = v p^w$. Freer trade will lead to an increase in v and would further lower p if the good is imported and raises p if the good is exported.

Accordingly, world and domestic price are assumed linked through

(1) $$p = \beta p^w,$$

where β measures the impact of trade frictions and p^w is the world price of X. From the above analysis, in case of importation, β is greater than 1, and in case of exportation, β is less than 1.

Assume that firms have access to an abatement technology that requires a part of the production of goods X to protect the present environment. Let the gross output of a firm be x and x_a be the part that is used for abatement, then the net output is x_n = $x - x_a = x(1 - \frac{x_a}{x}) = x(1 - \theta)$, where $\theta = \frac{x_a}{x}$ is a measure of the intensity of abatement.

Denote the pollution emissions as z and emission per unit of X produced as $e(\theta)$. If the firms devote more output to abatement, then the contaminative emission will be less. Thus $e(\theta)$ is decreasing in θ, that is $e'(\theta) < 0$. Let us assume that the firms have not some interest to do some abatement by imposing $e'(0) = -\infty$. However, let us assume that there is a limit to protect the environment, that is $e(1)>0$. We can write the pollution emissions function as the following:

(2) $$z = e(\theta)x.$$

Production Firms

Firms maximize their profits. Firms must allocate their revenue in this model through four channels. First, they use part of their production to reduce pollution or use revenue to fund the firms' abatement costs. Second, they have to pay for the wage to the labor. Third, they must pay the return to capital. The above two items are for the firms the factor payments. Fourth, the firms pay the taxes to the government as they produce pollution. Thus, we can write the profit function as

$$\pi^x = px - p\,\theta x - wL_x - rK_x - \tau e(\theta)x$$

(3) $$= p^N x - wL_x - rK_x$$

where $p^N = p - p\theta - \tau e(\theta)$ is the net producer price for gross output. Technology is assumed constant returns to scale, so profit is equal to zero. The first-order condition of equation (3) with respect to θ is:

$$(4) \qquad p = -\tau e'(\theta).$$

From equation (4), we see that θ is a function of the ratio of pollution tax to the domestic price τ/p, which means $\theta = \theta(\tau/p)$. When the tax-price ratio increases, the government is putting more pressure on protecting the environment and forces the firms to forego more output to abate pollution. Thus, we have $\theta' > 0$. Also from equation (4), we can derive and get:

$$(5) \qquad e'(\theta) = -p/\tau = e'(\tau/p)$$

where $e'(\theta) < 0$, which implies logically that as the intensity of abatement increases, the quantity of the emission declines. In addition, following the zero profit condition, the prices of goods should be equal to its unit costs and hence we have:

$$(6\text{-A}) \qquad p^N = c^x(w, r) \qquad 1 = c^y(w, r)$$

The equilibrium conditions for the factor markets require that supply equals its respective demands:

$$(6\text{-B}) \qquad K = c_r^x x + c_r^y y \qquad L = c_w^x x + c_w^y y.$$

Consumers

In this model, there are two kinds of consumers in the society. One group is called Green and is denoted by N^g whereas the other is called Brown and is denoted by N^b. Logically, we have $N^b = N - N^g$. Preferences are homothetic, so that utility depends on real per capita income denoted by $\frac{G/N}{\rho(p)}$ and the level of pollution emission z where G is national income (so G/N is per capita income) and $\rho(p)$ is the consumption price index. Green consumers care more about the environmental problems than Brown consumers. This is specified by assuming that Green consumers suffer a greater disutility from pollution than Browns. We can write the indirect utility function of a consumer in the ith group as

$$V^i(p, G/N, z) = u(I) - \delta^i z = u(\frac{G/N}{\rho(p)}) - \delta^i z \quad (7)$$

For $i = \{g, b\}$ and where $\delta^g > \delta^b \geq 0$.

Government

To optimize social welfare, the government maximizes a weighted sum of each group's preferences:

$$\max_{\tau} N[\lambda V^g + (1-\lambda)V^b] \quad (8)$$

where λ is the weight put on Greens. The optimal pollution tax maximizes the weighted sum of the utilities in equation (8) subject to private sector behavior, production possibilities, fixed world prices, and fixed trade frictions. Putting equation (7) into equation (8), we get

$$\max_{\tau} N\{\lambda[u(I) - \delta^g z] + (1-\lambda)[u(I) - \delta^b z]\}$$
$$\max_{\tau} N\{[\lambda u((I) + (1-\lambda)u(I)] - [\lambda\delta^g z + (1-\lambda)\delta^b z]\}$$
$$\max_{\tau} N\{u(I) - [\lambda\delta^g z + (1-\lambda)\delta^b z]\}$$

Taking the first-order condition of the above equation with respect to τ, we have

(A) $$u'(I)\frac{dI}{d\tau} - [\lambda\delta^{g} + (1-\lambda)\delta^{b}]\frac{dz}{d\tau} = 0$$

The revenue of the government G is assumed to be composed by the revenue of the private sector $R(p^N, K, L)$ and the pollution tax τz.

$$G = R(p^N, K, L) + \tau z$$

With fixed world prices we have the real per capita national income as

$$I = \frac{G/N}{\rho(p)} = \frac{[R(p^N, K, L) + \tau z]/N}{\rho(p)}$$

$$= \frac{1}{N\rho(p)}[R(p^N, K, L) + \tau z]$$

Now the revenue of the private sector is made up of four items: the profits of goods X and goods Y respectively, wages of the labor and the return of the capital. Consequently, we have

$$R(p^N, K, L) = (p^N x - wL_x - rK_x) + (y - wL_y - rK_y) + (wL_x + rK_x) + (wL_y + rK_y)$$

$$= p^N x + y$$

From the above equation, we know that

$$p^N = p - p\theta - \tau e(\theta)$$

So it is logical to have

$$\frac{dR(p^N, K, L)}{dp^N} = x$$

and $$\frac{dp^N}{d\tau} = -e(\theta)$$

Hence the first-order condition of I should be

$$\frac{dI}{d\tau} = \frac{1}{N\rho(p)}[R_{p^N}\frac{dp^N}{d\tau} + z + \tau\frac{dz}{d\tau}]$$

$$= \frac{1}{N\rho(p)}\{x[-e(\theta)] + z + \tau\frac{dz}{d\tau}\}$$

By equation (2) $e(\theta)x$ is the amount of the pollution emission z. So the above equation may be changed to

(B) $$\frac{dI}{d\tau} = \frac{\tau}{N\rho(p)}\frac{dz}{d\tau}$$

We replace $\frac{dI}{d\tau}$ in equation (A) by equation (B), and get

$$u'(I)\frac{\tau}{N\rho(p)}\frac{dz}{d\tau} = [\lambda\delta^g + (1-\lambda)\delta^b]\frac{dz}{d\tau}.$$

Manipulating, we get successively:

$$u'(I)\frac{\tau}{N\rho(p)} = \lambda\delta^g + (1-\lambda)\delta^b,$$

$$\tau = N[\frac{\lambda\delta^g\rho(p)}{u'(I)} + \frac{(1-\lambda)\delta^b\rho(p)}{u'(I)}];$$

and finally

(9) $$\tau = N[\lambda MD^g(p, I) + (1-\lambda)MD^b(p, I)],$$

where $MD^i = \frac{\delta^i\rho(p)}{u'(I)}$ is the marginal damage per person and as the income increases, more goods are produced and hence more pollution is generated, which implies that $MD_I^i > 0$. If we use $\Phi(p, I)$ to denote $\rho(p)/u'(I)$, we can rewrite equation (9) as

(10) $$\tau = T\Phi(p, I)$$

where $T = \lambda N\delta^g + (1 - \lambda)N\delta^b$ is country specific. If a country prefers to clean the environment (large λ and large δ^g), then it would have stringent pollution policies and the level of pollution in that country would be lower. In addition, the level of pollution is related to the economic condition of a country. That is to say, if a country has a relatively higher economic condition (large S), then it can afford more resources to the environment.

Pollution comes from production and can therefore be treated as a kind of goods. In equilibrium, supply and demand eventually determine the price of the goods. In order to explore the importance of international trade, it is necessary to find out how other different economic factors affect the demand for, and supply of, pollution. The trade's impact on pollution can be decomposed into three effects: the scale effect, the technical effect and the composition effect. As described above, if a country's income improves though freer trade, then the pollution in the country should also increase. This is the scale effect, which is positive. However, an increased income induced by freer trade can also help the country to apply better techniques and more strict environmental policies to protect the environment. In this case, the level of pollution will be lower. So the technical effect reduces pollution. As for the composition effect, international trade may lead to changes of the structure of importation or exportation. If the country exports more polluting goods, then the level of pollution would increase. The sign of the composition effect is thus indeterminate and depends on which goods are exported and imported.

The demand for pollution

The private sector generates pollution by producing goods. The production of pollution is thus inevitable. The demand for pollution is implicitly defined by equation (2) which states that $z = e(\theta)x$. Note that the private sector's production x is a part of the national output, denoted by φS where φ is the share of x in total output and S stands for national output at base-year prices. So we can write:

(11) $$S = p_x^0 x + p_y^0 y$$

To simplify the interpretation, the base-year prices are assumed to be equal to unity. In this case, S is in fact the economy's scale. Thus equation (2) can be changed to

(12) $$z = e(\theta)x = e(\theta)\varphi S$$

In differential form, we get

(13) $$\hat{z} = \hat{S} + \hat{\varphi} + \hat{e}$$

The above equation provides a simple decomposition: the level of pollution depends on the pollution intensity of the dirty industry $e(\theta)$, the share of x in total output φ, and the scale of the economy S. Any change of one of the three items changes the level of pollution. In equation (13), the three items on the right-hand side are respectively the scale effect, the composition effect and the technique effect.

From equation (6), we can get the share of x in total output φ as a function of the ratio of capital to labor $k = K/L$ and the net price p^N, that is to say, $\varphi = \varphi(k, p^N)$. The differential form is given by

(14) $$\hat{\varphi} = \varepsilon_{\varphi\kappa}\hat{\kappa} + \varepsilon_{\varphi\kappa}\hat{p}^N,$$

where the elasticity of φ with respect to κ and p^N are all positive. From the above analysis, we know that

$$p^N = p - p\theta - \tau e(\theta) = p(1 - \theta) - \tau e(\theta).$$

Putting equation (1) into the above equation, we get

$$p^N = \beta p^w (1 - \theta) - \tau e(\theta)$$

so $$dp^N = (1 - \theta)(p^w d\beta + \beta dp^w) - e(\theta)d\tau$$

From $p^N = p(1 - \theta) - \tau e(\theta)$, we know $(1 - \theta) = [p^N + \tau e(\theta)]/p$ and rewrite the above equation as

$$dp^N = (p^w d\beta + \beta dp^w)\frac{p^N + \tau e(\theta)}{p} - e(\theta)d\tau.$$

Manipulating, we have step by step:

$$dp^N = \frac{p^w d\beta + \beta dp^w}{p}[p^N + \tau e(\theta)] - e(\theta)d\tau$$

$$dp^N = \frac{p^w d\beta + \beta dp^w}{\beta p^w}[p^N + \tau e(\theta)] - e(\theta)d\tau$$

$$dp^N = (\frac{d\beta}{\beta} + \frac{dp^w}{p^w})[p^N + \tau e(\theta)] - e(\theta)d\tau$$

$$dp^N = (\hat{\beta} + \hat{p}^w)[p^N + \tau e(\theta)] - e(\theta)d\tau$$

$$\hat{p}^N = \frac{dp^N}{p^N} = (\hat{\beta} + \hat{p}^w)\frac{1 + \tau e(\theta)}{p^N} - \frac{e(\theta)}{p^N}d\tau$$

$$\hat{p}^N = (\hat{\beta} + \hat{p}^w)\frac{1 + \tau e(\theta)}{p^N} - \frac{\tau e(\theta)}{p^N}\frac{d\tau}{\tau}$$

Using α to replace $\tau e(\theta)/p^N$ and rewriting the above equation, we get

(15) $$\hat{p}^N = (\hat{\beta} + \hat{p}^w)(1 + \alpha) - \alpha\hat{\tau}$$

Similarly, we can also find the function of $\hat{e}$ from equation (1): $p = \beta p^w$ and equation (5): $e'(\theta) = -p/\tau = e'(\tau/p)$, as following:

(16) $$\hat{e} = \varphi_{e,\frac{p}{\tau}}(\hat{\beta} + \hat{p} + \hat{\tau})$$

As we know, if $e'(\theta) = e'(\tau/p)$ is less than zero, then the elasticity of e with respect to p/τ will be positive.

After all these manipulations, we get the final decomposition function of the private sector's demand for pollution,

$$(17) \quad \hat{z} = \hat{S} + \varepsilon_{\varphi,\kappa}\hat{\kappa} + [(1+\alpha)\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}}]\hat{\beta} + [(1+\alpha)\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}}]\hat{p}^{w} - [\alpha\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}}]\hat{\tau}$$

where all coefficients are all positive. From the above equation, we can get that an increase in scale S, capital abundance κ, or the world price of dirty goods p^{w} will make more pollution. In $\{z, \tau\}$ space, any increase in scale, capital abundance and the world price will shift the pollution demand curve to the right.

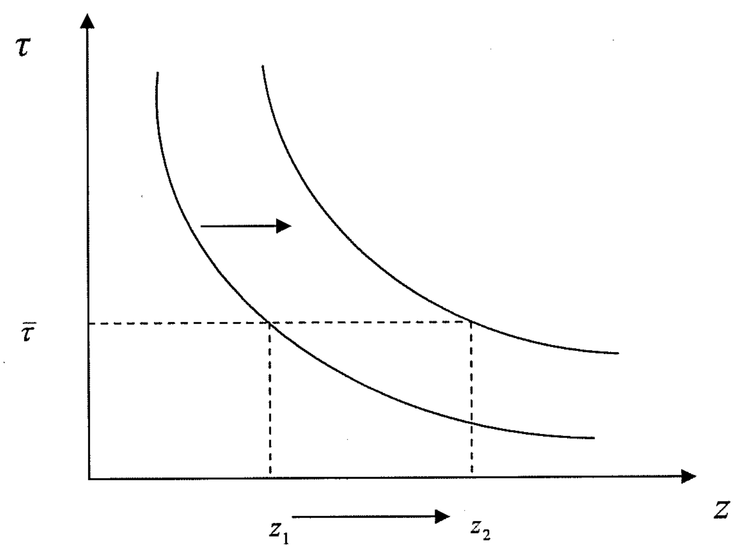


Figure 2: pollution demand curve

As to the change of trade friction $\hat{\beta}$, we have two situations. A movement of β toward *1* means a reduction in trade friction. Since β is greater than *1* to an importer and is less than *1* to an exporter, the change of β should be negative to the importer and positive to the exporter, which implies that the sign of the change of β is changing. Furthermore, the change of the level of pollution should be negative to the importer and be positive to the exporter. The following graph shows the change of the level of pollution with respect to a reduction in the trade friction as to an importer. (Note that the graph that shows the change of the level of pollution with respect to a reduction in the trade friction as to an exporter is the same as Figure 2.)

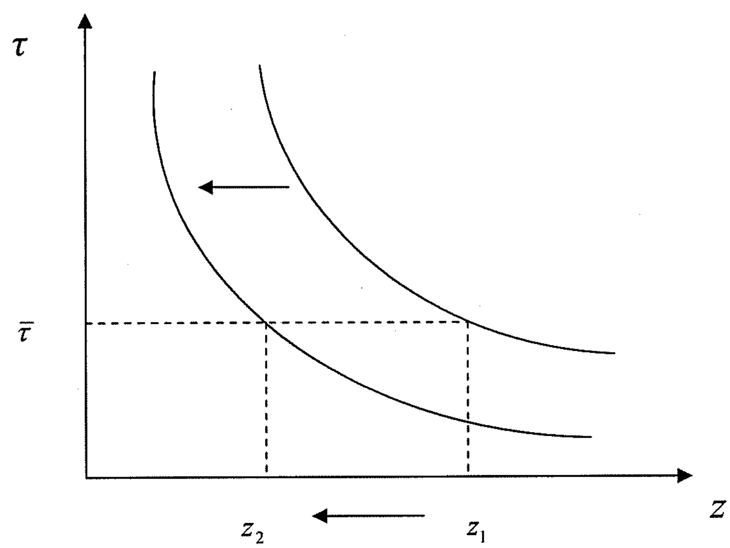


Figure 3: Pollution demand curve to an importer holding other factors constant

Also from equation (17), an increase in the pollution taxes charged by the government leads to a decrease in the level of pollution. In economic terms, if the government charges higher pollution taxes, on one side, the private sector has to pay more resources to reduce the pollution, so the emission intensity would be reduced. On the other side, higher pollution taxes affect the international pattern such that the private sector has a lower net price and hence reduces the production amount of output x. The two effects can be captured by the elasticity of e with respect to p/τ and the elasticity of φ with respect to p.

The supply of pollution

We now focus on the government who sets the pollution taxes based on the level of pollution. At one extreme, the government can eradicate the production of pollution. So, in some extent, the problem of pollution can be treated as the consequence of the government's policy. In this model, the government should be the supplier of the pollution, since it has the power to control the level of pollution by imposing the pollution taxes.

Combining equation (1) to equation (10), we obtain the decomposition of pollution supply,

$$\hat{\tau} = \hat{T} + \varepsilon_{MD,p}\hat{\beta} + \varepsilon_{MD,p}\hat{p}^{w} + \varepsilon_{MD,I}\hat{I} \qquad (18)$$

where all the coefficients should be positive. From the above equation, we can see that an increase in the real income I, the world price p^{w} and the country type T lead to an increase in the level of pollution taxes and further to a decrease in the level of pollution. To explain, we put the change into the $\{z, \tau\}$ space like the following,

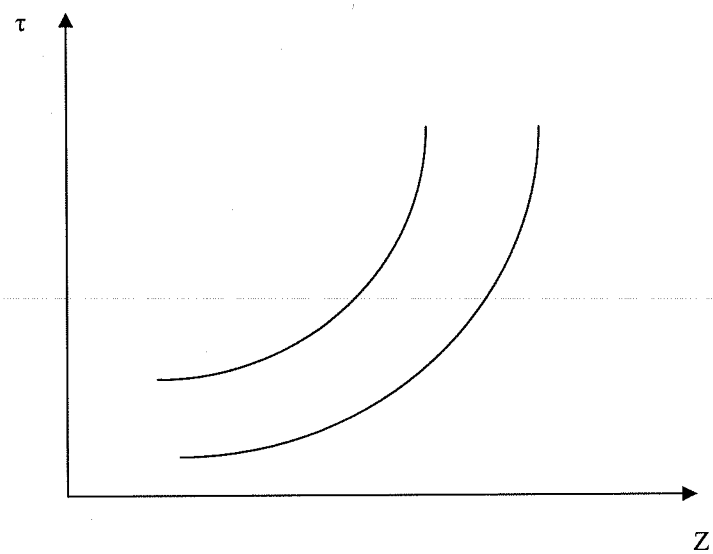


Figure 4: pollution supply curve

It is worthy noting that an increase in the country type implies that the country has more "green" people and thus the government should meet the need of "cleaner" environment and set more stringent pollution policies.

Similarly, the falling of trade friction β creates two effects. As we know, a fall of β is negative to an importer and is positive to an exporter. Furthermore, from equation (18), a rise in the pollution taxes $\hat{\tau}$ is negative to the importer and positive to the exporter, and the pollution supply curve shifts downward to the importer and upward to the exporter. So the change of the pollution level $\hat{z}$ is positive for the importer and negative for the exporter.

Now, a reduced form linking pollution emissions to a small set of economic factors can be developed from the combination of the demand for the pollution, that is equation (17), and the supply of the pollution, that is equation (18).

(19) $$\hat{z} = \pi_1\hat{S} + \pi_2\hat{\kappa} - \pi_3\hat{I} + \pi_4\hat{\beta} + \pi_5\hat{p}^w - \pi_6\hat{T}$$

where all π_i are positive. There are two points that should be noted.

First, although equation (19) gives the relationship between pollution level and all economic factors, none of the right-hand-side variables are determined simultaneously with emissions. Note that $R(p^N, K, L) + \tau z = p(1 - \theta)x + y$, which is independent of z. A society may decide to spend some of its potential income on improving environmental quality and the rest of it on consumption goods. However, if the pollution level increases, the potential income will not be raised correspondingly. Furthermore, pollution taxes are responding to the pollution level, but the equilibrium level of emission does not affect pollution taxes. As a result, real income, pollution level and pollution taxes are set simultaneously, whereas emissions are set recursively.

Second, any change of the world prices p^w and a reduction of the trade friction β will shift pollution supply and demand in opposing directions, so the signs of the coefficients π_4 and π_5 are not necessarily positive. In order to solve this problem, ***PROPOSITION 1*** restricts the signs of the above two coefficients.

PROPOSITION 1[19]: *Consider two economies that differ only in their trade friction: (i) if both countries export the polluting good, then pollution is higher in the country*

[19] Werner Antweiler, Brian R. Copeland and M. Scott Taylor 2001, "Is Free Trade Good for the Environment?", American Economic Review 91(4), 877-908: 884

with lower trade frictions; (ii) if both import the polluting good, then pollution is lower in the country with lower trade frictions.

To be obvious, we draw the following graph,

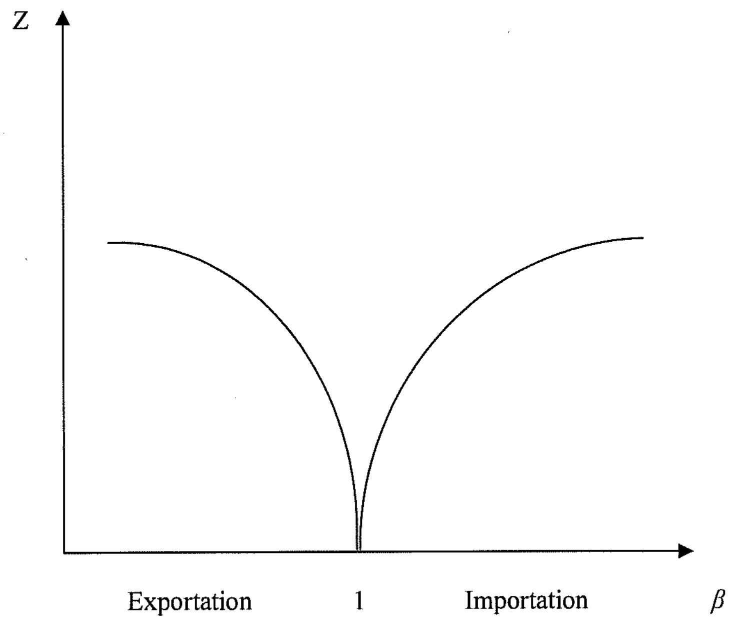


Figure 5

PROOF OF PROPOSITION 1:

Using equation (17) and (18) and holding *T*, *S*, *I*, *K/L* and p^w constant, the change of the pollution level $\hat{z}$ can be rewritten in the following form,

$$\hat{z} = [(1+\alpha)\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}}]\hat{\beta} - [\alpha\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}}]\hat{\tau}$$

and $$\hat{\tau} = \varepsilon_{MD,p}\hat{\beta}$$

so $$\hat{z} = [\varepsilon_{\varphi,p} + (\alpha\varepsilon_{\varphi,p} + \varepsilon_{e,\frac{p}{\tau}})(1-\varepsilon_{MD,p})]\hat{\beta}$$

By Roy's identity, we can show that as real income *I* is held constant, the elasticity of $\varepsilon_{MD,p}$ is equal to the ratio of the consumption amount of output x to the total consumption. That is to say $\varepsilon_{MD,p}$ is less than 1. Thus, from the above equation, z rises as β rises. This creates two situations: as to a dirty good importer, a decrease in the trade friction β means the international trade becomes easier. So if the trade is freer, the pollution level will be lower; as to a dirty good exporter, increased openness corresponds to an increase in β, and hence all else equal, a reduction in trade frictions raises pollution.

PROPOSITION I can figure out the sign of the composition effect whose sign is changing across countries. For an importer of the polluting good, β declines with freer trade and this decreases the relative price of the dirty good X and increases the relative price of the clean good Y. This shifts a dirty good importer's pollution demand curve to the right and shifts its pollution supply curve down. Pollution demand shifts inside for two reasons: the composition of national output does not shift toward X; and emission intensities decline because abatement inputs are now cheaper. The shift in the pollution supply curve aggravates the pollution as the pure substitution effect of the goods price decrease leads the government to reduce the pollution taxes. However, the direct demand-side effects offset the substitution effect in supply, and pollution decreases[20]. Consequently, holding all other determinants of pollution supply and demand constant, emission must decrease. This reduction in emissions represents the trade-induced composition effect for a clean good importer.

---

[20] To see this, note that the decrease in τ is less than proportional to the decrease in β, because decrease in τ induced by β is a pure substitution effect, which is proportional to the share of X in consumption (which is less than one). This ensures both that emission intensity e decreases, and that the share of X in production decreases.

Although ***PROPOSITION 1*** is useful and can isolate the sign of the composition effect, there is a limit in it. Any fall in trade frictions may affect the scale and the technique of the economy which can make the pollution level different, so the full environmental impact of a fall in trade frictions should not be accounted only by ***PROPOSITION 1***.

4. A Numerical Analysis of the Impact of Trade on Environment

The above model we presented is a theoretical general equilibrium model of trade to determine how a fall in trade barriers affects pollution levels. We now want to use a CGE model to investigate further the link between trade and pollution.

The model we use is taken from Lavoie, Mérette and Souissi (2001). It is a multi-sector, multi-country, computable general equilibrium (CGE) model with perfect competitive markets. We assume that there are three regions in the model, namely: Country A, Country B and Country C. There are three sectors by region, namely: Agriculture, Manufacture and Services. Agriculture and manufacture are tradable goods and services are non-tradable goods. In any sector of any region, goods are heterogeneous. That is to say, the agriculture good produced in Country B is not identical to the agriculture good produced in Country A. The only modification we make to the model is to add pollution by assuming as in Antweiler et al (2001) that pollution is generated by production activity. Below we describe briefly the model. Details can be found in Lavoie, Merette and Souissi (2001).

We postulate that there is a representative agent by region and this agent maximizes a Cobb-Douglas utility function,

$$\underset{c_{i,s}}{Max}\, U(c_{i,s}) = \prod_{s} c_{i,s}^{\rho_{i,s}}$$

subject to its budget constraint:

$$PC_i C_i = \sum_{s} Pc_{i,s} c_{i,s}$$

$$\sum_{s} \rho_{i,s} = 1 .$$

The household in each region determines the quantity of consumption and investment. Formally, the preferences of the household with respect to geographic origin of the goods consumed are represented by a constant elasticity of substitution function (CES). The optimal composition of its consumption basket in terms of geographic and firm origin is given by the solution of the following optimisation problem:

$$\underset{c_{j,i,s}}{Max}\, c_{i,s} = [\sum \delta_{j,i,s} c_{j,i,s}^{\frac{\sigma_{c,s,i}-1}{\sigma_{c,s,i}}}]^{\frac{\sigma_{c,s,i}}{\sigma_{c,s,i}-1}} \text{, if } s \text{ is produced in a competitive sector}$$

subject to:

$$Pc_{i,s} c_{i,s} = \sum_{j} (1+\tau_{j,i,s}) P_{j,i,s} c_{j,i,s} \text{, if } s \text{ is competitive}$$

Where:

$c_{j,i,s}$: consumption by country i of good s produced in country j,

$P_{j,i,s}$: price in country i of good s produced in country j,

$\sigma_{c,s,i}$: Armington elasticity of substitution for consumption in country i between good s produced by competitive firms,

$\delta_{c,s,i}$: consumption share parameters in country i for good s produced by competitive firms,

$\tau_{j,i,s}$: tariff rate on good s purchased by country i from country j.

In this model, we also suppose that firms operate under perfect competition. The firm's objective is to maximise its profits. The first-order condition to this problem is the usual equality between price and marginal cost. Technologies are constant returns to scale. So the cost minimization problem is,

$$\underset{L_{i,s},K_{i,s},X_{i,sd,s}}{Min} \quad v_{i,s}Q_{i,s} = w_i L_{i,s} + r_i K_{i,s} + \sum_{sd} Px_{i,sd,s} X_{i,sd,s} \ ,$$

subject to a Cobb-Douglas condition:

$$Q_{i,s} = L_{i,s}^{\alpha_{L_{i,s}}} K_{i,s}^{\alpha_{K_{i,s}}} \prod_{sd} X_{i,sd,s}^{\alpha_{X_{i,sd,s}}} \ ,$$

where:

w_i : wage rate in country i,

$L_{i,s}$: quantity of labour in sector s,

r_i : rental rate of capital in country i,

$K_{i,s}$: stock of capital in country i,

$Px_{i,sd,s}$: average price paid by sector s of country i for goods sd,

$X_{i,sd,s}$: average price paid by sector s of country i for goods sd,

α_s : share parameters.

In addition, as firms operate with constant returns to scale technologies, the share parameters sum to one:

$$\alpha_{L_{i,s}} + \alpha_{K_{i,s}} + \sum_{sd} \alpha_{X_{i,sd,s}} = 1.$$

The inputs of production depend on labour (*L*), capital (*K*) and intermediate goods (*X*). The firm's demand with respect to geographical and firm origin of a commodity *sd* is assumed to be a CES aggregation function of inputs from all possible sources. The solution to the following problem determines the share from each origin:

$$MaxX_{i,sd,s} = [\sum_j \eta_{j,f,i,sd,s} X_{j,f,i,sd,s}^{\frac{\sigma_{x,s,i}-1}{\sigma_{x,s,i}}}]^{\frac{\sigma_{x,s,i}}{\sigma_{x,s,i}-1}}$$, if *sd* is produced by competitive firms,

subject to:

$$Px_{i,sd,s} X_{i,sd,s} = \sum_j (1+\tau_{j,i,sd}) P_{j,i,sd} X_{j,i,sd,s}$$, if *sd* originates from competitive firms,

where:

$X_{j,i,sd,s}$: amount of intermediate inputs purchased by sector s of country i from sector *sd* in country *j*,

$X_{j,f,i,sd,s}$: amount of intermediate inputs purchased by sector s of country i from firm *f* of sector *sd* in country *j*,

$P_{j,i,sd}$: price of goods *sd* sold by country *j* to country *i*,

$P_{j,f,i,sd}$: price of goods *sd* sold by firm *f* of country *j* to country *i*,

α_s : share parameters,

$\sigma_{x,s,i}$: Armington elasticity of substitution of sector s in country i, for intermediate inputs produced by competitive firms.

Production activities generate pollution. We assume that pollution in country j (z_j) equals:

$$z_j = \sum_{Q} Q_{i,s}\beta_{i,s} ,$$

where $\beta_{i,s}$ is the output-pollution matrix. $\beta_{i,s}$ determines how much pollution is generated from output $Q_{i,s}$.

The equilibrium conditions close the model. In equilibrium, supply equals demand in goods and factor markets. We notice that the balance of payments is always in equilibrium. We use the General Algebraic Modeling System (GAMS) software to solve the CGE model and to do a series of fictive simulation exercises. Specific coding for GAMS is available upon request.

5. Simulation Results

We conduct three experiments to evaluate the impact of trade liberalization on environment. First, we simulate tariff changes effects on environment when countries are symmetrical. Second, we revisit *PORPOSITION 1* by assuming that a country has comparative advantages in producing some of the goods. Third, we investigate the pollution levels of the three countries when the world economy is composed by small and large economies.

Experiment 1: The impact of tariff changes

Four points should be noted before this first experiment. Firstly, the three economies are assumed to be perfectly symmetric at the initial equilibrium. They have the same size, same preference, and produce the same goods in the same proportion with respect to GDP. Secondly, agriculture and manufacture goods are tradable and service goods are non-tradable. Thirdly, the tariff matrix is also symmetric across regions and is assumed a 10 percent tariff rates for the agriculture and manufacture goods.

Table 1: Tariff Rates

	Agriculture	Manufacture	Services
C_A	0.1	0.1	0
C_B	0.1	0.1	0
C_C	0.1	0.1	0

In Table 1, C_A, C_B, C_C refer to Country A, Country B, and Country C respectively. The tariff rate for Services is nil as this kind of good is assumed non-tradable. Fourthly, the pollution parameter matrix is like the following:

Table 2: Pollution parameter matrix (β)

	Agriculture	Manufacture	Services
C_A	0.5	0.5	0.1
C_B	0.5	0.5	0.1
C_C	0.5	0.5	0.1

The pollution parameters are symmetric across countries. Agriculture and manufacture goods pollute equally and more than services.

In the first experiment, we change the tariff of the three countries. In Scenario 1, all tariffs are reduced. In Scenario 2, all tariffs rise. Scenario 3 and Scenario 4 consider the case when one country becomes more open to trade while the other becomes more protectionism. We summarize the results of the experiments in Table 3. We report the results of the simulation in indices terms, where at the initial equilibrium all values equal one.

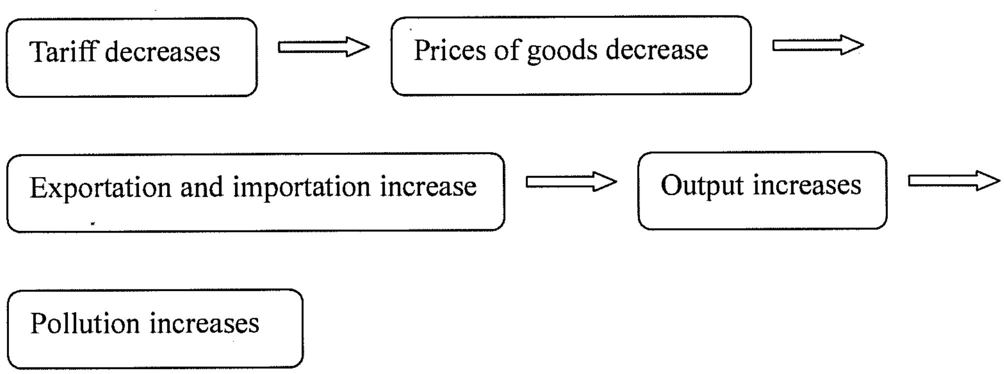
Table 3: The impact of tariff's reduction on gross output

Change of the Tariff Rates		Gross Output			Pollution Level
		AGRIC	MANUF	SERVI	
Original		1.000000	1.000000	1.000000	1.000000
Tariff cuts 25% by three countries	C_A	1.025535	1.025025	1.024901	1.001840
	C_B	1.025535	1.025025	1.024901	1.001840
	C_C	1.025535	1.025025	1.024901	1.001840
Tariff increases 25% by three countries	C_A	0.998111	0.997704	1.003792	0.998492
	C_B	0.998111	0.997704	1.003792	0.998492
	C_C	0.998111	0.997704	1.003792	0.998492
Tariff cuts 50% by C_A and increases 50%by C_B	C_A	1.004963	1.010587	0.985902	1.005602
	C_B	0.995689	0.990551	1.012466	0.995043
	C_C	1.000039	0.999722	1.000217	0.999914
Tariff cuts 25% by C_A and increases 50% by C_B	C_A	1.002465	1.005826	0.992484	1.002987
	C_B	0.995795	0.991540	1.011474	0.995437
	C_C	1.000101	1.000651	0.999318	1.000271

Note: C_A: Country A, C_B: Country B, C_C: Country C

In Scenario1, with a tariff reduction by 25% in all three countries, the gross outputs of all sectors in all countries increase, and hence the pollution levels of all countries also increase. For example, the tariff reduction in the three countries rises the output of agriculture, manufacture and service to 1.025025, 1.025025 and 1.024901 respectively. The pollution level is hence increased to 1.001840 in three countries. As illustrated in Figure 6, a drop in tariff reduces the prices of exporting or importing goods and hence stimulates exportation and importation. Naturally, the overall output of the economies increases. As a result of more production activity, pollution level increases. The results are symmetric across countries as they are perfectly identical at the initial equilibrium. The impact on the sectors agriculture and manufacture is greater than on the services sector as the first two are tradable and the last one not.

Figure 6



On the contrary, when tariff increases by 25% in all three countries, the gross outputs of all sectors in all countries decrease, and hence pollution levels also decline in all countries.

In Scenario 3, tariff declines by 50% in Country A but increases by 50% in Country B. As shown in Table 3, the outputs of agriculture and manufacture in

Country A increase to 1.004963 and 1.010587 respectively, and those of agriculture and manufacture in Country B decrease to 0.995689 and 0.990551 respectively. The pollution level of Country A increased to 1.005602 and that of Country B decreases to 0.995043. This is consistent with the fact that tariff's reduction helps to increase the output of an economy and hence to raise the pollution level. As to the service sector, the change is inconsistent with the above fact because services are non-tradable goods. Thus, a relative low-tariff country gets a higher pollution level and a relative high-tariff country can get a lower pollution level.

In Scenario 4, when tariff rates decline by 25% in Country A and increases by 50% in Country B, the outputs of agriculture and manufacture in Country A increase to 1.002465 and 1.005826 respectively, and those of agriculture and manufacture in Country B decrease to 0.995795 and 0.991540 respectively. The pollution level of Country A increases to 1.002987 and that of Country B decreases to 0.995437. The most important is that, as to Country C, the output increases and the pollution level increases to 1.000271. This is a case related to a relative low-tariff country and a high-tariff country in which high-tariff will hinder the international trade with other countries. The tariff in Country B is so high that Country A would like to trade with Country C. So outputs and pollution levels of Country A and Country C tend to increase.

The simulation results of ***Experiment 1*** confirm that trade can affect pollution levels through production activity. In particular, free trade can increase pollution by stimulating output.

Experiment 2

In this experiment, we keep most of the parameters as in Experiment 1 except we assume that in the initial equilibrium, Country A is specialize in the production of the agriculture goods, Country B in the production of the manufacture good, and Country C in the production of services. The matrix of production below indicates the level of production of each good in each country.

Table 4: The output of each country

	Agriculture	Manufacture	Services
C_A	2637.273	1532.727	2910.000
C_B	1532.727	2637.273	2910.000
C_C	1532.727	1532.727	2910.000

The pollution parameter matrix is now like the following:

Table 5: Pollution parameter matrix

	Agriculture	Manufacture	Services
C_A	0.6	0.3	0.1
C_B	0.6	0.3	0.1
C_C	0.6	0.3	0.1

From the above matrix, we see that agriculture is assumed to be the most polluting production activity. Services goods are relatively clean. Obviously, Country A generates more pollution than the other two countries as the initial equilibrium as it is produces more of the agriculture goods. In the simulation exercise, we first decrease tariff rates by 25% everywhere. Then we reduce tariff rates between Country A and Country B by 50%. The simulation results are reported in Table 6.

Table 6

		Tariff rates decrease by 25% everywhere		Tariff rates decrease by 50% in Country A and Country B	
		Gross Output	Pollution Level	Gross Output	Pollution Level
Initial		1.000000	1.000000	1.000000	1.000000
C_A	Agric	1.015334	1.005547	1.029757	1.011086
	Manuf	0.976265		0.956397	
	Servi	0.998596		0.995976	
C_B	Agric	0.972530	0.993694	0.951313	0.989341
	Manuf	1.015980		1.030288	
	Servi	0.999986		0.998194	
C_C	Agric	1.005795	1.002957	1.003916	1.001934
	Manuf	1.001628		1.000747	
	Servi	0.996089		0.997543	

Note that Agric: Agriculture, Manuf: Manufacture and Servi: Services

Following the comparative advantage concept, Country A should produce more of agriculture goods with free trade, and Country B should produce more of the manufacture goods. From Scenario 1 in Table 6, we see that with a decline of tariffs by 25% everywhere, Country A increases its production of agriculture goods to 1.015334 and Country B increases its production of manufacture goods to 1.015980. Since agriculture goods are more polluting than manufacture goods, the pollution level of Country A rises by more than that of Country B.

In this simulation, Country A is the largest exporter of the polluting goods. As trade is liberalized, Country A not only pollutes more but its trade partner benefits from a cleaner environment. This is consistent with ***PROPORSITION 1*** which suggests that exporting the polluting goods leads to more pollution with free trade. Notice that Country C produces more of the agriculture and manufacture goods when the tariff rates decline.

Experiment 3: The impact of the size of countries

In this experiment, we keep the same technology pollution parameters as in *EXPERIMENT 2*. We make, however, Country A smaller and Country B larger at the initial equilibrium. We repeat the same tariff shocks as applied for *EXPERIMENT* 2. The simulation results are reported in Table 7.

Table 7

		Tariff rates decrease by 25% everywhere		Tariff rates decrease by 50% in Country A and Country B	
		Gross Output	Pollution Level	Gross Output	Pollution Level
Initial		1.000000	1.000000	1.000000	1.000000
C_A	Agric	1.016855	1.0005988	1.034130	1.012671
	Manuf	0.973081		0.949660	
	Servi	0.998891		0.995553	
C_B	Agric	0.991969	0.997469	0.993772	0.998301
	Manuf	1.003284		1.003687	
	Servi	1.001724		1.000520	
C_C	Agric	1.005751	1.002551	1.000934	1.000527
	Manuf	0.999615		1.000554	
	Servi	0.997276		0.999244	

The results go in the same direction as for *EXPERIMENT 2*. However, compared to *EXPERIMENT 2*, the rate of change of pollution in the small country is higher than in the large country. For example, when tariffs decrease by 25% in the three countries, the rate of change of pollution in Country A is greater by 7.95% in *EXPERIMENT 3* than in *EXPERIMENT* 2. The opposite statement applies for Country B. Scenario 2 confirms Scenario 1 results.

EXPERIMENT 3 simulation exercises thus suggest that the impact of trade on pollution is likely to be larger for small countries.

Caveats

We can easily identity three caveats in these simulation exercises. First, more modeling effort would be necessary to really capture the scale effect, the technique effect and the composition effect as developed in the theoretical literature. Second, this is a numerical model and the data set is fictive. If possible, we will use real economic data in a future research. Third, this model ignores pollution policy that government may apply to protect the environment. That is to say, we do not distinct the demand for pollution and the supply of pollution in this model.

6. Conclusion

The purpose of this paper is to discuss the relationship between international trade and environment. Based on the *pollution haven hypothesis* and the alternative *factor endowment hypothesis*, we started by reviewing the literature. The literature suggests that the impact of international trade can be divided into scale, technique and composition effects. We detailed a theoretical model to investigate the three effects and to specify the demand for pollution and the supply of pollution. Then, we use a computable general equilibrium model to investigate the issue further.

As a result, we find in the simulation experiments that pollution is closely related to production activity of an economy. International trade can benefit an economy's growth and thus increase pollution level. Trade friction plays an important role in the relationship between international trade and environment. Low tariff rates can make the environment dirtier or cleaner. As suggested by *PROPOSITION 1*, freer trade by pushing up outputs of comparatively advantageous goods can increase pollution if the exportation goods are more polluting. We also show that pollution level of a third country can be affected by trade policies between the other two countries. Finally, the size of the impact on pollution after a change in tariff rates is sensitive to the size of the countries involved.

References

Antweiler A., Brian Copeland and M. Scott Taylor (2001), "Is Free Trade Good for the Environment", *American Economic Review* 91(4), 877-908.

Copeland, Brian and M. Scott Taylor (1994), "North-South Trade and the Environment", *Quarterly Journal of Economics*, August, 755-787.

Copeland, Brian and M. Scott Taylor (2004), "Trade, Growth and the Environment", *Journal of Economic Literature XL11*, March, 7-71.

Copeland, Brian, and M. Scott Taylor (2003), *Trade and the Environment: Theory and Evidence*, Princeton University Press.

Grossman G. M and A. B.Krueger (1993), "Environmental Impacts of a North American Free Trade Agreement" in *The US-Mexico Free Trade Agreement*, P. Garber, ed. Cambridge, MA: MIT Press.

Grossman G. M and A. B. Krueger (1995), "Economic Growth and the Environment", Quarterly Journal of Economics, 353-377.

Lavoie Claude, Marcel Mérette and Mokhtar Souissi (2001), "A Multi-Sector Multi-Country Dynamic General Equilibrium Model with Imperfect Competition", Department of Finance Working Paper.

Monitoring Ambient Air Quality for Health Impact Assessment, WHO Regional Publications, European Series, No. 85.