Globalization and Environment in the Presence of Cross-border Pollution

By

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Abstract

We construct a two-country, two-good general equilibrium model of international trade where pollution from production is transmitted across borders. Governments in both countries impose emission taxes non-cooperatively. Within this framework, we examine the effect of trade liberalization on Nash emission taxes, emission levels, and welfare. We also examine how the endogeniety of terms of trade affects Nash pollution taxes and total emission level.

Key Words: Cross-border pollution, Emission taxes, Terms of trade shocks, Welfare.


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1 Introduction

More than ever before, a dominant issue in current public policy debates among nations is that of international externalities associated with pollution generated in countries. This negative externality is allegedly exacerbated with liberalization of international economic activities (e.g., freer international mobility of goods and capital feverishly pursued nowadays by numerous countries and international institutions.\(^1\) In light of such perceived environmental degradation emanating from expanded economic activities, environmentally conscious political and social groups have been staging fierce worldwide reactions against international negotiations (e.g., the summits of WTO in Seattle, 2000, of IMF in Prague, 2001, and of the G-8 group in Geneva, 2001) promoting these objectives.

Accounting for such growing real world concerns, a sizable literature on the economics of international trade and cross-border pollution has and is being developed. A strand of this literature analyzes the implications of cross-border pollution and/or examining the welfare effects of selected pollution abatement (trade and environmental) policies (see, for example, Markusen, 1975; Copeland, 1994, 1996; Ludema and Wooton, 1994, 1997; Beghin et al., 1997; Hatzipanayotou et al., 2002, 2004.)

There is now a small theoretical literature that examines the effect of international trade on pollution. Raucher (2001) examines whether it is optimal to employ a policy of ‘ecological dumping’ in the presence of terms of trade considerations. Copeland and Taylor (2003) which synthesizes their earlier papers, examine the effect of trade liberalization on welfare in, and emission by, a small open economy which has optimal environment policies in place. They find that when the country adjusts its optimal policies in response to trade liberalization, more trade increases welfare but can, under certain circumstances, increase pollution. They also consider a model of two large countries to examine the economic logic.

\(^{1}\)See, for example, Copeland and Taylor (2003) for a discussion of the issues.
behind pollution havens. They investigate, *inter alia*, if trade driven by environmental policy differences is bad for the environment and find that it is not necessarily so.

In this paper we develop a two-country general equilibrium model with two-way cross-border pollution and terms of trade effects. Within this framework, we first characterize, in section 3, the non-cooperative optimal values for the emission tax rates when the terms of trade is exogenous. Also, we examine the effects of a reduction in trade costs on Nash optimal tax rates, net pollution and welfare in the two countries. In section 4, we examine how an endogeniety of the terms of trade affects the optimal tax rates. Finally, some concluding remarks are offered in section 5.

## 2 The Theoretical Framework

We consider a general equilibrium model with two countries – home and foreign – where pollution as a by-product of production is generated in both countries, and it is transmitted across national borders.

The two countries produce, under perfectly competitive conditions, two goods – good 1 and good 2 – which are freely traded in world markets. Good 1 is the *numeraire* commodity. Regarding international prices, we consider the cases where the international (relative) price of the non-numeraire good 2 is either exogenous (*eg.* when both economies are small in the world commodity markets) or it is endogenously determined (*eg.* when both economies are large in the world commodity markets). Factors of production are internationally immobile and inelastically supplied. Factor markets in both countries are perfectly competitive. Producers in the two countries abate some of the pollution they generate in response to government imposed emission taxes at the rate $t$ and $t^*$ respectively.\(^2\) Let $e$ and $e^*$ denote the level of pollution emission in the two countries. As has been shown by Copeland and Taylor (2003, ch.4), the effect of trade liberalization on pollution depends on, *inter alia*, the

\(^2\)The variables in the foreign countries are marked with asterisks.
patterns of trade. We shall examine the implications of the patterns of trade for the results in our framework later on.

For simplicity, we shall assume that only one of the two goods is polluting.\(^3\) Which is the polluting good would depend on the nature of the goods and the type of pollutant we consider. For example, if the home country is a developing country which typically exports agricultural goods and the pollutant is industrial waste, then good 1 is the pollutant. If, on the other hand, the pollutant is nitrates in the water supply, then good 2 is possibly the pollutant. We shall leave the assumption open for the time being.

We proceed now to spell out the model for the home country; the model of the foreign country follows analogously. The country’s maximum value of production is denoted by the gross domestic product, or revenue function, \(R(p, t, v)\), defined as:

\[
R(p, t, v) = \max_{x_1, x_2, e} \{x_1 + px_2 - te : (x_1, x_2, e) \in T(v)\},
\]

where \(p\) is the world price of the non-numeraire good, \(T(v)\) is the country’s aggregate technology set,\(^4\) \(x_1\) and \(x_2\) are the outputs of good 1 and good 2 respectively, \(v\) is the vector of endowments, \(e\) is the amount of pollution emission and \(t\) is the emission tax rate. Since total endowments of all factors of production, \(v\), are exogenously given, for notational simplicity, it can be suppressed and the revenue function can be written simply as \(R(p, t)\). Its partial derivative with respect to \(p\) (i.e., \(R_p\)) denotes the supply function of the non-numeraire good 2. It is also known (e.g., see Copeland, 1994, and Turunen-Red and Woodland, 1998) that its partial derivative with respect to \(t\) multiplied by \(-1\) is the amount of pollution emissions by the private sector, i.e.,

\[
e = -R_t(p, t).
\]

Analogously, for the foreign country we have

\[
e^* = -R^*_t(p^*, t^*)
\]

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\(^3\)For simplicity, we consider only one type of pollution.

\(^4\)It includes abatement technology in addition to production technology.
The revenue function is strictly convex in commodity prices (i.e., $R_{pp} > 0$) and in the emission tax rate (i.e., $R_{tt} > 0$). The later property indicates that an increase in the emission tax rate lowers the amount of pollution emission by the private sector. Moreover, if good 2 is the polluting one, a higher emissions tax rate ($t$) reduces the level of its production, i.e., $R_{pt} < 0$. If, on the other hand, good 1 is the polluting one, we shall have $R_{pt} > 0$. Since we do not make any presumption on the pattern of trade, we shall, without any loss of generality, assume that the non-numeraire good is the polluting good in both countries so that $R_{tp} < 0$ and $R^{*}_{t^*p} < 0$.

Turning to the demand side of the home economy, utility, $(u)$, as previously noted is adversely affected by both local pollution, $e$, and by foreign pollution, $e^*$ transmitted across borders. Denoting by $\theta$ the spill-over parameter, welfare in the home country is adversely affected by $z = e + \theta e^*$. Let $E(p, z, u)$ be the expenditure function which gives minimum expenditure required by a representative consumer to achieve a given level of utility $u$ given commodity (consumers’) price $p$ and aggregate level of pollution $z$. The partial derivative of the expenditure function with respect to $u$, $E_u$, gives the reciprocal of marginal utility of income, and that with respect to $p$, $E_p$, gives the compensated demand function of the non-numeraire good. Since pollution is a public bad, the partial derivative of the expenditure function with respect to $z$, $E_z$, is positive and denotes the households’ marginal willingness to pay for a reduction in pollution (e.g., see Chao and Yu, 1999). The expenditure function is also strictly concave in $p$, i.e., $E_{pp} < 0$, and strictly convex in $z$, i.e., $E_{zz} > 0$. The later property implies that a higher level of pollution raises the households’ marginal willingness to pay for its reduction. Moreover, we also make the natural assumption that $E_{zu} > 0$, that is, a higher level of real income increases the households’ marginal willingness to pay for pollution abatement. Finally, $E_{pz} \leq 0$, depending on whether cleaner environment and good 2 are complements (i.e., $E_{pz} < 0$) or substitutes (i.e., $E_{pz} > 0$) in consumption. Note that an increase in $z$ increases expenditure for a given utility level, i.e., $E_z > 0$. This increase in expenditure has to involve an increase in consumption of at least one of the two goods. For
the quasi-linear direct utility function of the form: 
\[ u(c_1, c_2, z) = v(c_2) + \lambda_1 c_1 - f(z), \]
where \( c_i \) is the consumption of good \( i \) (\( i = 1, 2 \)), and \( \lambda_1 \) is a given constant, cleaner environment and the non-numeraire good are independent in consumption, i.e., \( E_{pz} = 0 \), and all the adjustments of a change in \( z \) (at a given utility level) fall on the numeraire good.\(^5\) One can also think of a situation where a higher level of pollution induces people to consume less of the polluting good and in this case cleaner environment and polluting (the non-numeraire) good are complements, i.e., \( E_{pz} < 0 \).

The budget constraint for representative consumer requires that total expenditure \( E(p, z, u) \) must equal factor income from the production of the two traded goods \( R(p, t) \) plus the emission tax revenue \( (te) \) that the government returns to the representative consumer in a lump-sum fashion. That is,

\[ E(p, z, u) = R(p, t) + te. \tag{3} \]

Analogously, for the foreign country we have

\[ E^*(p, z^*, u^*) = R^*(p, t^*) + t^*e^*, \tag{4} \]

where \( z^* = e^* + \theta^*e \) and \( \theta^* \) is the spill-over parameter for the foreign country.

Imports of the non-numeraire good are given by

\[ M_p(p, z, t, u) = E_p(p, z, u) - R_p(p, t) \]

with \( M_{pp} < 0 \), \( M_{pz} = E_{pz} \) is positive (negative) depending on whether cleaner environment and good 2 are substitutes (complements) in consumption, and \( M_{pt} = -R_{pt} \). \( M_p^*(p, z^*, t^*, u^*) \) is similarly defined with similar properties.

When terms of trade are endogenously determined, the world market-clearing condition for the non-numeraire good is given by:

\[ M_p(p, z, t, u) + M_p^*(p, z^*, t^*, u^*) = 0. \tag{5} \]

With exogenous terms of trade, equations (1)-(4) constitute a system of four equations in four unknowns, namely \( u, u^*, e \) and \( e^* \). In this case, the model contains two policy parameters, one for each country, and these are the emission tax rates \((t, t^*)\), and an exogenous parameter, namely the terms of trade \((p)\) for each country. When terms of trade are endogenous, equations (1)-(5) constitute a system of five equations containing five unknowns, namely the previous four and \( p \).

We conclude this section by examining how the policy parameters affect endogenous variable of our model. Differentiating equations (1) to (4) we obtain the changes in the level of home and foreign country welfare, when terms of trade are exogenous, as follows:

\[
du = A_p \, dp + A_t \, dt + A_{t^*} \, dt^*, \\
du^* = B_p \, dp + B_{t^*} \, dt^* + B_t \, dt,
\]

where

\[
E_u A_p = (E_z - t)R_{tp} - M + \theta R_{t^*p} E_z, \quad E_u A_t = R_{tt}(E_z - t) \\
E_u A_{t^*} = \theta E_z R_{t^*t^*}, \quad E_u B_p = (E_z^* - t^*)R_{t^*p} - M^* + \theta^* R_{tp} E_z^*, \\
E_u B_{t^*} = R_{t^*t^*}(E_z^* - t^*), \quad E_u B_t = \theta^* E_z^* R_{tt}.
\]

We proceed by explaining equations (6). In doing so we shall ignore marginal utilities of income \((1/E_u \text{ and } 1/E_u^*)\) which simply converts incomes to utilities. Equation (6) indicates that there are three effects on \( p \) on \( u \): (i) the well-known terms-of-trade effect \((-Mdp)\); an improvement in the term of trade increases welfare, and (ii) an effect via changes in tax revenue \((-tR_{tp})\); and (iii) an effect via changes in disutility of pollution from changes in pollution in the home country \((E_z R_{tp})\) and that from cross-border pollution\((E_z R_{t^*p})\). If, for example, the home country is an importer of the non-numeraire good \((M > 0)\), an improvement in its terms of trade \((dp < 0)\) increases welfare, i.e. the first effect is positive. Since the non-numeraire good is the polluting one, we have \( R_{tp} < 0 \) and then the second effect
is positive and the third effect negative. In this case, the net effect of an improvement in terms of trade is positive if $E_z \geq t$.

An increase in the own tax rate $t$ entails a positive impact on welfare if and only if pollution is socially under-taxed (at a given $p$), i.e., $E_z > t$. Finally, the last term in equation (6) ($A_{t^*} dt^*$) captures international tax externality. It says that an increase in one country’s emission tax rate unambiguously raises the welfare of the other country by reducing cross-border pollution. Equation (7) can similarly be explained.

To incorporate the effects of the policy instruments ($t$ and $t^*$) on each country’s welfare through induced changes in the terms of trade we proceed as follows. Totally differentiating (5) and solving with respect to $dp$ in terms of ($dt$ and $dt^*$) we obtain:

$$H dp = H_t dt + H_{t^*} dt^*,$$

where

$$H = E_{pp} + E_{pp}^* - R_{pp} - R_{pp}^* - (E_{pz} + \theta^* E_{pz^*}^*) R_{tp} - (E_{pz^*}^* + \theta E_{pz}) R_{t^* p^*}$$

$$+ (E_{pu} A_p + E_{pu}^* B_p)$$

$$H_t = (E_{pz} + \theta^* E_{pz^*}^*) R_{tt} + R_{pt} - (E_{pu} A_t + E_{pu}^* B_t)$$

$$H_{t^*} = (\theta E_{pz} + E_{pz^*}^*) R_{t^* t^*} + R_{p t^*} + (E_{pu} A_{t^*} + E_{pu}^* B_{t^*})$$

Note that Walrasian stability for the world commodity market requires that $H < 0$. The effect of $t$ on $p$ would depend on how the world demand and supply of the non-numeraire good is affected by $t$. Broadly, speaking there are three effects: (i) it will reduce the supply of the good from the home country since $R_{pt}$ is assumed to be negative and this will work toward reducing the equilibrium value of $p$, (ii) the increase in pollution tax reduces pollution which, in turn, will reduce the demand if and only if the non-numeraire good and cleaner environment are complements in consumption in the two countries ($(E_{pz} + \theta^* E_{pz^*}) R_{tt} < 0$), and this will reduce $p$ and finally (iii) an income effect via changes in utilities in the two
counties \((- (E_{pu} A_{t*} + E_{pu*} B_{t*}))\). If \(E_z > t\) the income effects from both countries would increase \(p\).

Substituting (8) into equations (6) and (7) gives the changes in \(u\) and \(u^*\) when the terms of trade is endogenous as follows:

\[
\begin{align*}
  du &= (A_t + A_p H^{-1} H_t) \, dt + (A_{t*} + A_p H^{-1} H_{t*}) \, dt^*, \\
  du^* &= (B_t + B_p H^{-1} H_t) \, dt + (B_{t*} + B_p H^{-1} H_{t*}) \, dt^*.
\end{align*}
\]

(9) \(10\)

Equation (9) indicates that with endogenous terms of trade there is an additional effect through induced changes in the terms of trade of \(t\) on \(u\), \(viz., A_p H^{-1} H_t\), and an additional effect of \(t^*\) on \(u\), \(viz. A_p H^{-1} H_{t*}\). Similar comments hold for (10).

3 The case of small open economies

In this section we shall assume that the two countries are small open economies, i.e., they face exogenous terms of trade \((dp = 0)\) and are connected only via two-way cross-border pollution, i.e., equations (5), (8), (9) and (10) will be ignored here. The analysis here is an extension of Copeland and Taylor (2003, ch. 4) where they consider a single small open economy affected by its own pollution. We shall first of all characterize Nash optimal emission tax rates (section 3.1), and then examine the effect of a change in the exogenous terms of trade on the optimal tax rates (section 3.2) and on welfare and emission levels (section 3.3). As pointed out by Copeland and Taylor (2003, ch.4), an improvement in the terms of trade can be equivalently interpreted as a decrease in trade costs of the iceberg type.

3.1 The Nash Equilibrium

Having explained the welfare equations, we can now characterize the non-cooperative Nash optimal levels of the policy instruments, \(i.e.,\) when the two countries choose respectively the
levels of \((t, \text{ and } t^*)\) simultaneously by maximizing their respective welfare, with each country treating the other’s policy parameters as given. That is:

\[
\frac{\partial u}{\partial t} = A_t = 0, \quad \frac{\partial u^*}{\partial t^*} = B_t = 0.
\]

Since the terms of trade is exogenous and the cross-border externalities are not internalized, the optimality conditions give the well-known Pigouvian rule, i.e., the tax rate in each country is equal to the marginal willingness to pay for pollution reduction:

\[
E_z = t, \quad E_z^* = t^*.
\] (12)

However, since the two countries are related via cross-border pollution, the two equations in (12) simultaneously determine the optimal (Nash) values of the policy instruments in the two countries.

3.2 Globalization and optimal policies

We now turn to examine the effect of an exogenous change in the terms of trade on the Nash emission tax rates \((t \text{ and } t^*)\). Differentiating the two equations in (11), we obtain:

\[
A_{tt}dt + A_{tt^*}dt^* = -A_{tp}dp,
\] (13)

\[
B_{t^*}dt + B_{t^*t^*}dt^* = -B_{t^*p}dp,
\] (14)

where using (12) we obtain:

\[
A_{tt} = -E_{zz}R_{tt} - 1 < 0
\]

\[
A_{tt^*} = \theta R_{tt^*}^* (E_{zz} + E_{ztu}) = \theta (E_z/z)(-\varepsilon_{zz} + \eta_{zu})R_{tt^*}^*.
\]

\[
A_{tp} = E_{zp} - (R_{tp} + \theta R_{t^*p}^*)E_{zz} + E_{u}^{-1}E_{zu} (\theta t R_{t^*p}^* - M)
\]

\[
= E_{zp} - ME_{u}^{-1}E_{zu} + (E_z/z)[\theta R_{t^*p}^* \eta_{zu} - (R_{tp} + \theta R_{t^*p}^*)\varepsilon_{zz}],
\]

where \(\varepsilon_{zz} = (z/E_z)E_{zz}\) is the home country’s elasticity of marginal willingness to pay for pollution abatement with respect to pollution, and \(\eta_{zu} = -\partial (1/E_u)/\partial z)(zE_u) = zE_u^{-1}E_{zu}\).
is the absolute value of the home country’s elasticity of the marginal utility of income with respect to pollution. \( B_{t^*t^*}, B_{t^*t} \) and \( B_{t^*p} \) are similarly defined.

From equations (13) and (14) we obtain the effect of an exogenous terms of trade change on the countries Nash tax rates as follows:

\[
\Omega \cdot \frac{dt^o}{dp} = -A_{tp} B_{t^*t^*} + A_{tt^*} B_{t^*p} \tag{15}
\]

\[
\Omega \cdot \frac{dt^o}{dp} = -A_{tt} B_{t^*p} + B_{t^*t} A_{tp}, \tag{16}
\]

where, \( \Omega = A_{tt} B_{t^*t^*} - A_{tt^*} B_{t^*t} > 0 \) for the stability of the Nash equilibrium, and the superscript ‘’o’’ denotes the Nash optimal values of the policy instruments.

Observing equation (15) and (16) we note that the effect of an exogenous terms of trade shock on Nash optimal tax rates is in general ambiguous. However, we can derive a set of sufficient conditions under which the above derivatives can be signed. Suppose that the following conditions are satisfied: (i) the non-numeraire good and cleaner enviroment are complements or independent in consumption, i.e., \( E_{zp} \leq 0, \ E_{z^*p} \leq 0 \), (ii) both countries import the non-numeraire good, i.e., \( M > 0, \ M^* > 0 \), and (iii) the income effect on consumers’ willingness to pay for reduced pollution is sufficiently high; in particular for home

\[
\eta_{zu} > [1 + (R_{tp} / (\theta R_{t^*p}^*))] \epsilon_{zz} \quad \text{and} \quad \eta_{z^*-u^*}^* > [1 + (R_{t^*p}^* / \theta^* R_{tp})] \epsilon_{z^*-z^*}^*,
\]

then, since \( R_{tp} < 0, \ R_{t^*p}^* < 0 \), it can be shown that \( A_{tp} < 0, \ B_{t^*p} < 0, \ A_{tt^*} > 0 \) and \( B_{t^*t} > 0 \). More, we already know that \( A_{tt} < 0 \) and \( B_{t^*t^*} < 0 \). Therefore, under the conditions (i)-(iii) we shall have \( dt^o/dp < 0 \) and \( dt^o/dp < 0 \). That is, under these sufficient conditions, improvements in the terms of trade of the two countries \( (dp < 0) \) increases the optimal Nash taxes.

The second term and a part of the first term in (15) appear because of the presence of cross-border pollution. Trade pattern is also important in signing \( dt^o/dp \) as can be seen from the second term in the definition of \( A_{tp} \); in fact, an improvement in the terms of trade would tend to increase \( t^o \) via this effect. However, the cross-border effect can, in theory, outweigh
this effect. If, for example, $\eta_{zu} < \epsilon_{zz}$ and $\eta_{*z} * u < \epsilon_{*z} * z$, it is possible that an improvement in terms of trade reduce levels of optimal emission taxes in the two countries.

### 3.3 Terms of Trade, welfare, and pollution emission

In this section, assuming that both countries are at Nash equilibrium, i.e., the two equations in (12) are satisfied, we examine the impact of an exogenous terms-of-trade change on welfare levels $u$ and $u^*$ and pollution levels $e$ and $e^*$. First of all, when the two countries do not respond to a terms-of-trade change by adjusting the optimal taxes, it can be seen from (6) and (7) that welfare in both countries will increase from terms-of-trade improvements if the importing sector in each country is the polluting one. Note that Copeland and Taylor (2003, ch. 4) showed that when a small open economy does not respond to a terms-of-trade change by adjusting its optimal emission tax, welfare in the country will unambiguously increase as a result of an terms-of-trade improvement. In the present case, because of the presence of cross-border pollution from a second country, this is no longer necessarily the case. If, for example, the country is an exporter of the non-numeraire good which is also the polluting good, an improvement in the terms of trade will increase the relative price of the polluting good in the other country, increase its production, thus increasing cross-border pollution into the home country. Since cross-border pollution is not taken into account while setting optimal emission taxes, a terms of trade improvement can indeed reduce welfare even when the emission taxes are at the Nash optimal levels.

When the countries adjust their optimal taxes in response to terms-of-trade shocks, differentiating equation (1) and using (12), for the home country we obtain:

\[
\frac{du}{dp} = A_p + A_t^* \cdot \frac{dt^*}{dp},
\]

\[
\frac{de}{dp} = -R_{tp} - R_{tt} \cdot \frac{dt}{dp},
\]

where the induced effect via changes in the optimal taxes are given by the second terms on
the right hand sides of (17) and (18). Note that whereas the effect on utility depends on induced changes in the tax rate in the foreign country,\(^6\) that on pollution emission depends on the induced changes in the tax rate in the home country.

Recall that \(A_t > 0\) and \(R_t > 0\), and thus the induced effects will increase welfare and reduce pollution emission if improvements in the terms-of-trade increases the optimal tax rates, sufficient conditions for which were developed in section 3.2. The analysis for the foreign country can be similarly conducted.

4  The case of endogenous terms of trade

In this section we shall consider the international terms of trade to be endogenous and examine what this does, at the margin, to the optimal emission taxes. In other words, we shall try to find out if the endogeniety of the terms of trade increases or decreases the Nash tax rates. We endogenise the terms of trade by assuming the two countries to be large open economies. This implies that we shall bring in equations (5), (8), (9) and (10) which were ignored in section 3.

For this exercise, we shall evaluate \(du/dt\) (as given in (9), i.e., when the terms of trade is endogenous) at the Nash equilibrium with exogenous terms of trade,\(^7\) and if sign of the derivative is positive (negative) then, assuming concavity of the country welfare functions, we shall be able to conclude that the Nash tax rate in the home country is higher (lower) when the terms of trade is endogenous than when it is exogenous. Thus, we need to determine the \(\text{sign}(A_pH^{-1}H_t)\) and \(\text{sign}(B_pH^{-1}H_t)\) when (12) is satisfied. When, for example, the sign of \((A_pH^{-1}H_t)\) is positive, we can conclude that the Nash tax rate in the home country is higher when the terms of trade is endogenous than when it is exogenous. It is already known that \(H > 0\). We therefore need to look more closely at \(A_p\), \(B_p\) and \(H_t\). When (12) is satisfied,

\(^6\)The effect via changes in the own country tax rate washes out due to the envelope theorem.
\(^7\)Implicitly, we assume that the level of the exogenous terms of trade is the same as that of the endogenous one.
these three terms simplify to:

\[ E_u A_p = (\theta t R_{tp}^* - M), \text{ and} \]
\[ E_u^* B_p = -M^* + \theta^* R_{tp} E_{pz}^*. \]
\[ H_t = (E_{pz} + \theta^* E_{pz}^*) R_{tt} + R_{pt} - E_{pz}^* B_t. \]

Since the non-numeraire good is the polluting one \((R_{tp} < 0, R_{tp}^* < 0)\), it follows that if the non-numeraire good and cleaner environment are complements or independent in consumption \((E_{pz} \leq 0, E_{pz}^* \leq 0)\), we have \(H_t < 0\). Note that \(E_u A_p + E_u^* B_p\) is always negative. Thus, both \(A_p\) and \(B_p\), cannot be positive. Moreover, if the non-numeraire good is the imported good in the home country (i.e., \(M > 0\)), we have \(A_p < 0\), but \(B_p\) can be positive since this good is exported by the foreign country (i.e., \(M^* < 0\)). Therefore, we can conclude that if the non-numeraire good and cleaner environment are complements or independent in consumption, the optimal Nash tax rate in the country which imports the non-numeraire good will unambiguously be higher when the terms of trade is endogenous than when it is exogenous. In the presence of cross-border pollution, but not in the absence of it, the optimal Nash tax rate can also be higher when the terms of trade is endogenous in the country that is an exporter of the polluting good. Consider, for example, the case of a developing country which exports agricultural goods and imports industrial goods, the pollutant is an industrial waste, and industrial goods and clean environment are complements in consumption. In this case, the optimal Nash tax rate for this developing country will be higher when the terms of trade is endogenous than when it is exogenous.

5 Concluding Remarks

In the absence of pollution, changes in world prices of traded goods affects welfare by changing the value of trade. This is the well-known terms-of-trade effect. For example, a decrease
in the relative price of the imported good increases welfare by decreasing the value of imports. In the presence of cross-border pollution, changes in world prices of goods affects welfare, in addition to the term-of-trade effect, by changing the levels of pollution and the Nash optimum pollution taxes. To address this issue, we build a two-country, two-good, general equilibrium trade model. The production of one of the goods in each country generates pollution which is transmitted in both countries and affects welfare. In response to pollution each country imposes a pollution tax in a non-cooperative fashion.

The reduction in the world price of the polluting good which is imported by the home country — which can be a result of a decrease in trade costs — improves its welfare by decreasing the cost of imports, but it can also increase welfare by decreasing pollution transmitted from the foreign country. For example, if this decrease in the price of the polluting good causes the foreign Nash emission rate to increase, then this indirect effect will strengthen the beneficial effect of a terms-of-trade improvement. The decrease in the price of the polluting good in fact causes foreign Nash emission rate to increase if, *inter alia*, the polluting good and clean environment are complements or independent in consumption and the two countries are importers of the polluting good. If, however, the country exports the polluting good, an improvement in its terms of trade may decrease its welfare.

We also find that if clean environment and the polluting good are compliments or independent in consumption in both countries, the endogeniety of the terms of trade increases the Nash optimum emission tax rates for the country that imports the polluting good, as compared to the case where the terms of trade is exogenous. The opposite can be true for the country that exports the pollution generating good.
References


