# ENVIRONMENTAL POLICIES AND TRADE LIBERALIZATION : A TIME CONSISTENCY ISSUE

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## *Abstract*

We examine the impact of trade liberalization on environmental policy, in a two-country, *n* firms model. In autarky, governments implement the environmental taxes maximizing social welfare and maintain social welfare at the same level regardless the firms'number. When trade cost decreases, firms compete non-cooperatively on both markets. Our main result is that there is a range of trade costs such that governments are not able to implement any optimal environmental policy. The less competitive are the markets the larger the range of trade costs leading to the time consistency problem. We show also that environmental policies are more stringent in open market but social welfare is lower than in autarky as long as trade cost is positive.

*Keywords*: Environmental tax; Bilateral trade; Time consistent policies.

*JEL code: F12, F18, H21*

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**Environmental policies and trade liberalization: a time consistency issue**


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## 1. Introduction

"Is free trade good for the environment?"[1] A large literature has tried to answer this question by analyzing the links between trade, environmental policies, governments and firms' strategies, most of the time in a two-country model with one or two firms. A part of this literature focuses on the fact that governments may strategically use environmental policies to impact on the pattern of trade, when tariffs are banned and firms' location are exogenous (Tanguay, 2001; Duval et al., 2002). Another part of the literature analyzes the problem of environmental tax competition among governments with multinational firms (Eerola (2004)) or with endogenous plant locations (Markusen et al. (1993)). All these papers stress that firms' location depends on different variables (fixed costs, transport costs, environmental standards, market size). Some of them show that governments may

act strategically in order to drive polluting firms to the other country, by setting a too tough environmental policy (Markusen et al. (1995) describe this NIMBY (Not In My Back Yard) case). At the opposite, governments may have an incentive to choose low environmental standards to attract more firms (see for example Motta et al. (1994), Hoel (1997)). Most of the time, when firms are mobile, there exist critical values of environmental standards leading to large discontinuities in welfare levels and this lack of continuity constrains most of the authors to proceed by simulations or comparative statics. Moreover, in this literature, governments act as Stackelberg leaders: they fix the environmental standard in a first stage and in a second stage firms compete non – cooperatively in quantity and/or choose their location, taking the governments' decisions as given. Petrakis et al. (2003) have shown, in a two-country, one firm model, that this temporal dimension may lead to time consistency issues when firm location decision is endogenous.

In the present paper, we also aim to introduce a temporal dimension in analyzing the impact of trade liberalization on environmental policies, with immobile firms. Starting from autarky, we assume that governments want to fix an environmental tax in order to maximize national global welfare[2] and we wonder whether, when trade liberalization occurs, the ex-post equilibrium delivers outcomes consistent with the ex-ante social choice. We consider a two-country model, but the framework of our model is more general than in the other models in the related literature since, in each country, $n$ firms ($1 \leq n < \infty$) produce a polluting homogenous good. This assumption enables us to highlight the relation between market structure and governments' environmental strategies. Moreover, we show that our results are robust regardless the firms' number.

In section 2 we present the general framework of the model. In section 3, we assume that at the beginning of the game, trade costs are so high that countries are in autarky. In that case,

governments are able to implement the environmental taxes maximizing social welfare (consumers 'surplus, profits, tax revenues minus the disutility of pollution) and maintain social welfare at the same level whatever the market structure.

Further (section 4), trade cost decreases and there is a limit value of trade cost such that firms are able to export if the autarky tax is held. When trade cost reaches this value, the best response of each firm is to export (see Brander and Krugman (1983)). Nevertheless, the autarky tax is no more the one maximizing global welfare. Now both governments and firms play a non cooperative game. Governments set in a first stage, the new optimal tax maximizing national social welfare in open economy. The second stage is a Cournot game where, firms compete non-cooperatively on both markets, taking as given the tax rates in both countries.

We show that the non cooperative equilibrium is not consistent with the social choice correspondence: because the new open market tax is higher than the autarky tax, firms are not able to export at the current level of trade cost. The main result is that there is a range of trade costs such that governments are not able to implement any optimal environmental policy. Section 5 analyzes the sub-optimal policy in this range of trade costs: regulators may set a sub-optimal tax, alternatively higher than the optimal autarky tax in order to prevent the firms from exporting or lower than the optimal open market tax in order to allow exports. In this last case, the exported quantities are very tiny and constant whatever the decrease in trade costs in the range leading to the time consistency problem.

Section 6 analyzes the open market impact on social welfare. Environmental policies are more stringent in open market than in autarky. Nevertheless social welfare decreases with trade because of the waste due to trade costs and because of more pollution.

We conclude in section 7.

## 2. The model

We consider a model of two identical countries (*i,j*), and a polluting industry consisting of *n* firms ($1 \leq n < \infty$)[3] in each country. Pollution is purely local. Assume one unit of polluting emission for each unit of output and $\gamma$ the marginal damage resulting from one unit of emission[4].

The firms' technology is described by a same constant marginal cost equal to zero. However, firms must pay a tax *t* on emissions[5]. In each country, there is an identical linear demand: $P = a - Q$[6]. Markets are segmented and we assume that firms must pay a linear trade cost, $S$, when they export.

Firms' profits depend on whether they are able or not to export and whether foreign firms export or not. Since Brander and Krugman (1983), we know that the rivalry of oligopolistic firms in segmented markets may lead to a two-way trade under the condition that the autarky price in each country exceeds the marginal cost of exporting (in our model pollution tax plus trade cost) by the other.

It follows that profits are determined by the interaction of one strategic variable (the pollution tax decided by regulators) and two parameters: trade cost, $S$, and marginal damage, $\gamma$. We consider the consequences of a decrease in trade cost (as the result of a regional agreement) on the environmental policy, for a given level of $\gamma$. Note that, deliberately, we do not explicitly interpret $S$ which, for example, may include tariff and non tariff barriers, foreign market accessibility, transport and distribution costs. The result of the agreement is a decrease in trade cost, by removing tariffs between members, but the final level of $S$ depends on the other trade cost's components.

In a first stage, each country' s regulator assesses a pollution tax, *t*, on emissions in order to maximize global welfare which is the sum of consumers' surplus, profits plus tax revenues

net of the disutility of pollution. In a second stage, firms compete non-cooperatively on both markets, taking as given the tax rates in both countries.

Assume first, as a benchmark, that trade cost level is so high that firms are not able to export .

**3. Autarky**

In each country, maximizing profits leads to a produced quantity by each firm equal to:

$$q_A = \frac{(a-t)}{n+1} \qquad (1)$$

and each firm's profit is given by: $$\Pi_A = \left(\frac{(a-t)}{n+1}\right)^2 \qquad (2)$$

The autarky equilibrium price is: $$P_A = \frac{(a+nt)}{n+1} \qquad (3)$$

The objective function of each government is:

$$W = CS + n\Pi + (t - \gamma)Q \qquad (4)$$

Where $CS$, $n\Pi$, $tQ$ are respectively the national consumers surplus, global profit and tax revenues (with $Q = n\, q_A$). $\gamma\ Q$ is the global environmental damage.

Governments chose the environmental tax in order to maximize $W$.

Substituting into (*4*), $q_A$ and $\Pi$ by their respective values (given by (*1*) and (*2*)), we obtain the optimal[7] environmental tax maximizing $W$ in autarky:

$$t_A = -\frac{a}{n} + \gamma\frac{(n+1)}{n} \qquad (5)$$

It is not surprising to remark that the optimal tax decreases when the market is less competitive $\left(\frac{dt_A}{dn} > 0\right)$ and tends to its pigouvian value ($t_A = \gamma$) when the firms' number

tends to infinite: because governments have only one instrument, the environmental tax, they use it in order to limit market's failures. By this way, the regulators maintain welfare at the same level, whatever the market structure. Substituting in (*4*) *t* by its optimal value $t_A$ (given by (*5*)), we see that global welfare does not depend on the firms' number. When governments are able to implement the autarky optimal tax, welfare in each country, is given by:

$$W_A = \frac{1}{2}(a-\gamma)^2 \qquad (6)$$

**4. Trade liberalization**

Assume now a decrease in trade cost as the result of a regional agreement between countries. As underlined above, country *j* firms will be able to export as soon as

$$P_A^i \rangle t_j + S \qquad (7)$$

where $P_A^i$ is country *i* autarky price given by (*3*). Remind that countries are identical (then $t_j = t_i$), it follows that condition for a two-way trade is:

$$S < \frac{(a-t)}{n+1} \qquad (8)$$

Starting from autarky and assuming a decrease in $S$, it is easy to determine the limit value of trade cost allowing firms to export when the autarky optimal tax given by (5) is fixed:

$$S \overset{\lim}{_{t_A}} = \frac{a-\gamma}{n} \qquad (9)$$

As soon as trade cost is lower than this value, firms compete non-cooperatively on both markets. Their best strategy is to export and the result of the game is a two-way trade.

With open market, firms maximize their profit separately on each segmented market.

The results of the Nash equilibrium are given by:

$$q_{open} = \frac{a - t + nS}{2n+1} \quad \text{and} \quad q^*_{open} = \frac{a - t - (n+1)S}{2n+1} \qquad \forall i, j \qquad (10)$$

where $q_{open}$ is the quantity produced for the national market and $q^*_{open}$ is the exported quantity[8] by each firm in each country. The corresponding profit for each firm is:

$$\Pi_{open} = \left( \frac{a - t + nS}{2n+1} \right)^2 + \left( \frac{a - t - (n+1)S}{2n+1} \right)^2 \qquad (11)$$

Nevertheless, the ex-ante tax ($t_A$) is no more optimal because governments' objective functions have changed with trade. Social welfare is still given by (4) but now consumers 'surplus must include the imported quantities, profits must include the exported quantities and, in each country, $Q = n\,(q_{open} + q^*_{open})$.

When firms export, countries' welfare is given by (using (10) and(11)):

$$W_{open} = \frac{1}{2}\left( \frac{2n(a-t) - nS}{2n+1} \right)^2 + n\left( \frac{a - t + nS}{2n+1} \right)^2 + n\left( \frac{a - t - (n+1)S}{2n+1} \right)^2 + (t - \gamma)\; n\left( \frac{2(a-t) - S}{2n+1} \right) \qquad (12)$$

Maximizing (12) leads to the ex-post optimal tax:

$$t_{open} = -\frac{a}{2n} + \frac{(2n+1)\gamma}{2n} + \frac{S}{4n} \qquad (13)$$

It is straightforward to see that this ex-post optimal tax is higher than the optimal autarky tax[9], and decreases with a larger firms' number. The reason of this higher level of environmental tax with trade is two-fold: first, the global production (then pollution) increases with trade (see Appendix 1) and the environmental policy is more stringent in order to compensate the worse global damage. Second, opening the markets leads to more competition and decreases the need to use environmental policy to limit markets' failures. It follows that the open market emission tax is closer to the pigouvian tax, hence higher, than the autarky one.

Environmental policies are more stringent in open market than in autarky[10].

Note also that the higher is the trade cost, the higher the open market emission tax. Trade cost has two opposite effects on the tax level. On the one hand, because trade cost reduces the pro-competitive effect of trade, the regulators have an incentive to lower $t_{open}$ with high values of *S*. On the other hand, since Brander and Krugman (1983) we know that opening the market between two symmetric oligopolistic markets may be welfare[11] decreasing, because of the waste due to trade cost (firms' outputs are perfect substitutes and imports cost more). It follows that governments have an incentive to use environmental policies to reduce trade by setting a higher tax for higher value of trade cost and this second effect over-balances the first one. We know also (see Brander and Krugman (1983)) that the pro-competitive effect of having more firms may counterbalance the negative effect of trade cost and that, with free entry, trade may be welfare improving. It follows that governments increase the open market tax with trade cost but this increase is softened when there are more firms.

Nevertheless, it is straightforward to see using (8) and (13) that the limit value of trade cost allowing firms to export when the optimal open market tax is fixed is:

$$S^{\lim}{}_{t_{open}} = \frac{2}{2n+1}(a-\gamma) \qquad (14)$$

As long as trade cost is higher than (or equal to) this limit value, firms are not able to export .

The principal result is that since $S^{\lim}{}_{t_{open}} < S^{\lim}{}_{t_A}$, the emission tax level $t_{open}$ determined in (13) is not time consistent for trade cost values such that $S^{\lim}{}_{t_{open}} < S < S^{\lim}{}_{t_A}$. In this range of trade costs, firms export if the autarky taxes are set and countries stay in autarky if they assess the open market taxes. Let us underline that the difference $(S_{t_A} - S_{t_{open}})$ decreases with a larger firms' number :

$$S_{t_A} - S_{t_{open}} = \frac{(a-\gamma)}{n(2n+1)}$$

Proposition 1 summarizes the results:

***PROPOSITION 1: There exists a range of trade costs such that an optimal environmental policy cannot be implemented when oligopolistic markets are open between two symmetric countries .***

***The less competitive are the markets the larger the range of trade costs leading to this time consistency problem.***

**5. Sub-optimal environmental policy**

In this section, we analyze the governments' sub-optimal policy for the range of trade cost's values between $S^{\lim}{}_{t_{open}}$ and $S^{\lim}{}_{t_A}$. In this range of trade costs, the autarky tax is no more optimal, because, at this level of tax, the firms' best strategy is to export and the open market tax is not optimal because, at this higher level of tax, firms cannot export and countries stay in autarky.

When trade cost reaches the value $S^{\lim}{}_{t_A} = \frac{a-\gamma}{n}$ then decreases until $S^{\lim}{}_{t_{open}}$, governments have two equivalent options.

- The first option is to set an emission tax higher than the autarky optimal tax in order to prevent firms from exporting. Remember that firms cannot export when $S \geq \frac{(a-t)}{n+1}$, governments may fix an emission tax $t \geq a-(n+1)S$. Because the autarky social welfare decreases when the emission tax moves away from the autarky optimal tax, governments will set the minimum tax allowing countries to stay in autarky. It follows that,

if governments choose to stay in autarky, the tax fixed for trade cost's values between $S^{\lim}{}_{t_A}$ and $S^{\lim}{}_{t_o}$ will be:

$$t_A^{subopt} = a - (n+1)S \qquad (15)$$

Note that, for $S^{\lim} = \frac{a-\gamma}{n}$, $t_A^{subopt}$ is equal to $t_A$ (given by 5). Afterwards, $t_A^{subopt}$ increases proportionally to the decrease in trade cost.

- The second option is to set an emission tax lower than the open market optimal tax in order to allow firms' exports. With a tax $t < a - (n+1)S$, firms are able to export. Because social welfare decreases when the emission tax moves away from the open market optimal tax, governments will set the maximum tax allowing firms to export, hence:

$$t_o^{subopt} = a - (n+1)S - \varepsilon \qquad (16)$$

If this sub-optimal tax is applied for each trade cost's values between $S^{\lim}{}_{t_A}$ and $S^{\lim}{}_{t_{open}}$, the exported quantities are very slight and constant in this range of trade costs.

Propositions 2 and 3 summarize the results.

***Proposition 2*** : *In the range of trade costs between* $S^{\lim}{}_{t_A}$ *and* $S^{\lim}{}_{t_{open}}$, *governments may set a sub-optimal tax in order to stay in autarky or alternatively in order to allow exports. Both alternatives are welfare equivalent* .

***Proposition 3****: The major consequence of the time consistency problem between environmental policies and trade liberalization is that a decrease in trade cost does not lead to more trade between* $S^{\lim}{}_{t_A}$ *and* $S^{\lim}{}_{t_o}$ .

Proof of these propositions are provided in appendix 2.

## 6. Welfare considerations

We have underlined in section 3, that in an oligopolistic market, international trade may be welfare decreasing. If this result is verified in our model, it is interesting to wonder

whether governments have an incentive to stay in autarky by keeping the sub-optimal tax (given by(15)), even when the time consistency problem is resolved by the decrease in trade cost below $S^{\lim}_{t_o}$.

Compare first the levels of welfare in autarky and in open market when the corresponding optimal environmental taxes ($t_A$ and $t_{open}$) are set.

Substituing in (12) $t$ by its optimal value $t_{open}$ given by (13), we obtain the open market welfare level:

$$W_{open} = \frac{n-1}{2n}\left((a-\gamma-\frac{S}{2}\right)^2 + \frac{1}{n}\left(\frac{a-\gamma}{2}+\frac{S(2n-1)}{4}\right)^2 + \frac{1}{n}\left(\frac{a-\gamma}{2}-\frac{S(2n+1)}{4}\right)^2 \qquad (17)$$

Let us first stress that, when $S=0$, the open market welfare is the same than in autarky. This value is given by (6) and does not depend on the firms' number. In that case, the governments succeed in maintaining the welfare at the autarky level, in spite of the increasing pollution.

Nevertheless, with a positive trade cost, governments have a supplementary problem: bounding the waste due to trade cost. We show in appendix 3 that, when $S>0$, the open market welfare is always lower than the autarky one. With only one instrument, the environmental tax, the governments do not achieve, in open market, to counterbalance the waste due to trade cost plus the increase in global damage resulting from more production. Consequently, we must verify if the regulators have an incentive to stay in autarky by setting the sub-optimal tax given by (15) even when $S$ reaches the value $S^{\lim}_{t_o}$.

Remember that, in the range of trade cost's values between $S^{\lim}_{t_{open}}$ and $S^{\lim}_{t_A}$, both options of the sub-optimal policy result in a nearly equivalent level of welfares, in autarky or in open market. Moreover, in the open market option, the sub-optimal tax (given by 16) leads necessarily to a lower level of welfare than the optimal tax, when this latter is possible (namely when trade cost has reached $S^{\lim}_{t_{open}} = \frac{2}{2n+1}(a-\gamma)$). Intuitively, it follows

that, the regulators will forsake the autarky sub-optimal policy and that exported quantities will begin to increase, as soon as trade cost will reach the limit value $S^{\lim}{}_{t_{open}}$.

Proof given in Appendix 4 sustains this intuition. .

***Proposition 4***: *With positive trade cost, a more stringent environmental policy is not sufficient to avoid a decrease in welfare with trade relatively to autarky. Nevertheless, regulators have no incentives to maintain the sub-optimal taxes in order to stay in autarky when the time consistency problem is resolved.*

**7. Summary and conclusions**

We develop a two-country model with a polluting industry and governments setting environmental taxes to maximize social welfare. We consider the consequences of a decrease in trade cost on the environmental policy. The model differs significantly from the related literature by assuming that there are *n* firms in each country and by considering the temporal dimension of the game between governments and firms. In autarky, governments are able to set the socially optimal environmental tax and limit markets' failures: they keep the social welfare at the same level regardless the firms' number. When trade cost decreases, there is a range of trade costs such that the non-cooperative game between firms leads to results not consistent with the governments' social choice. The lower is the firms' number, the larger the range of trade costs leading to the time consistency problem. In this range of trade costs, a sub-optimal tax may be set but this sub-optimal policy prevents firms from exporting even with lower trade costs. When the time consistency problem is resolved by a higher trade liberalization, governments may set the optimal open market taxes.

We show that the environmental policy is more stringent with trade than in autarky. Nevertheless, opening the market decreases social welfare relatively to autarky. Now the open market social welfare increases with lower trade costs and reaches the autarky level when trade cost is nullify.

In our model we have assumed symmetric countries for simplicity. Adding some asymmetries across countries (for example different market structures by assuming $n_i \neq n_j$) or/and among firms (for example different production costs) should be a fruitfull direction for future research. Unfortunately, it will be difficult to solve analytically this more general model. Another area for future research is to consider a transboundary pollution which favors cooperative environmental policies. In that case, it could be less probable to obtain time consistency issues.

**Appendix 1**

In autarky the global production is equal to $Q_A = \frac{n(a-t)}{n+1}$ and in open market $Q_{open} = \frac{2n(a-t)}{n+1} - \frac{nS}{2n+1}$. It is easy to verify that $Q_{open}$ is larger than $Q_A$ if $S < \frac{(2n+1)(a-t)}{n+1}$, condition always satisfied because trade occurs at the condition that $S < \frac{(a-t)}{n+1}$ (see (8)). Then, global damage is always increasing with trade.

**Appendix 2**

Assume that trade cost has reached some value between $S^{\lim}{}_{t_A}$ and $S^{\lim}{}_{t_o}$, and that governments have chosen to set the sub-optimal tax in order to stay in autarky.

Countries' welfare is given by:

$$W_A = \frac{1}{2}\left(n\left(\frac{a-t}{n+1}\right)\right)^2 + n\left(\frac{a-t}{n+1}\right)^2 + (t-\gamma)n\left(\frac{a-t}{n+1}\right) \quad (18)$$

Substituting into (18) *t* by its sub-optimal value given by (15), we obtain:

$$W_A^{subopt} = \frac{1}{2}(nS)^2 + nS^2 + (a-\gamma-(n+1)S)(nS) \quad (19)$$

Note that $W_A^{subopt}$ decreases with *S*: $\frac{dW_A^{subopt}}{dS} = (a-\gamma)n - n^2 S$ is positive if $S < \frac{a-\gamma}{n}$, which is the limit value $S^{\lim}_{t_A}$ defined in (9).

If governments have chosen to set the sub-optimal tax allowing firms' exports, the quantity exported by each firm is given by $q^*_{open}$ in (10 ). Substituing in (10) *t* by its value given by (16), we see that the quantities exported are very slight and constant whatever the decrease in trade costs in the range [$S^{\lim}_{t_A}$, $S^{\lim}_{t_o}$]:

$$q^*_{open} = \left(\frac{\varepsilon}{2n+1}\right)$$

Countries welfare is given by (12). Substituting into (12), *t* by its sub-optimal value given by (16), we obtain:

$$W_{open}^{subopt} = \frac{1}{2}\left(nS + \frac{2n\varepsilon}{2n+1}\right)^2 + n\left(S + \frac{\varepsilon}{2n+1}\right)^2 + n\left(\frac{\varepsilon}{2n+1}\right)^2 + (a-\gamma-(n+1)S-\varepsilon)\left(nS + \frac{2n\varepsilon}{2n+1}\right) \quad (20)$$

When the governments chose the open market solution, exportations (given by $n\left(\frac{\varepsilon}{2n+1}\right)$) are very tiny since the applied tax is the higher tax allowing trade. Moreover the sub-optimal taxes given by (15) and (16) are almost identical. Consequently the open market profits, consumers' surplus, tax revenues and damage in (20) are close to the autarky ones in (19). It follows that, in the sub-optimal game, the open market welfare is very close to the autarky one.

**Appendix 3**

Without trade cost, the open market production (then the pollution) in each country is twice the autarky one (see Appendix 1). Nevertheless, governments keep the welfare at the same level than in autarky: the open market welfare is equal to (see (17)):

$$W_{open} = \frac{n-1}{2n}((a-\gamma)^2 + \frac{1}{n}\left(\frac{a-\gamma}{2}\right)^2 + \frac{1}{n}\left(\frac{a-\gamma}{2}\right)^2 = \frac{1}{2}(a-\gamma)^2$$

When trade cost is positive, we obtain the difference between open market and autarky welfares by using (17) and (6). After some calculus, we have:

$$W_{open} - W_A = \frac{S^2(4n+1)}{8} - \frac{(a-\gamma)S}{2}$$

It follows that global welfare increases with trade at the condition that $S > \frac{4(a-\gamma)}{4n+1}$.

Now this condition is never satisfied since exports occur only if $S < \frac{2(a-\gamma)}{2n+1}$.

Consequently, welfare is always decreasing with trade relatively to autarky.

**Appendix 4**

We have to compare the autarky welfare value when governments assess the sub-optimal tax (given by 15) and the open market welfare when the optimal tax (given by 13) is fixed.

First, let us note that $t_A^{subopt} = a-(n+1)S$ is equal to $t_{open}$ (see 13) for $S=\frac{2}{2n+1}(a-\gamma)$.

Rearranging (17) and (19), we obtain:

$$W_{open} = \frac{1}{2}(a-\gamma)^2 - \frac{(a-\gamma)S}{2} + \frac{(4n+1)S^2}{8} \qquad \text{And} \qquad W_A^{subopt} = -\frac{1}{2}n^2S^2 + (a-\gamma)nS$$

It follows that ($W_{open}$ - $W_A^{subopt}$) is positive if S<$\frac{2}{2n+1}(a-\gamma)$ which is the limit level of trade cost allowing exports when the open market optimal tax is set (see(14)). For

$S=\frac{2}{2n+1}(a-\gamma)$, $W_{open} = W_A^{subopt} = \frac{2n(a-\gamma)(n+1)}{(2n+1)^2}$. When trade cost decreases below this value, $W_A^{subopt}$ continues to decrease ( see Appendix 2) and reaches zero for $S$=0. It follows that the regulators prefer to assess the optimal open market tax allowing trade as soon as $S=\frac{2}{2n+1}(a-\gamma)$. Note that, from this time, the level of the open market welfare is lower than the optimal autarky one but increases with lower trade costs and reaches the value $W_A = \frac{1}{2}(a-\gamma)^2$ when $S$=0.

**Notes**

[1] This question is asked by Antweiler et al. (2001).

[2] Governments are only able to implement this environmental tax ( they cannot use other instrument in order to control trade).

[3] We exclude the case of perfect competition ($n=\infty$) which cannot lead to trade because countries are exactly identical.

[4]We assume, for simplicity, a linear damage function. Using a quadratic function does not change the results.

[5]The environmental tax is equivalent to a tax on production.

[6] With $a > \gamma$ .

[7] More precisely, this tax is not "optimal" from an environmental point of view but is socially optimal from the global welfare point of view.

[8] It is easy to check that exports are positive iff (7) is verified.

[9] This is true for all values of $1 \leq n < \infty$. The difference ($t_{open} - t_A = \frac{a-\gamma}{2n} + \frac{S}{4n}$) is positive and tends to zero when the firms' number tends to infinite.

[10] Burguet et al. (2003) obtain the same result in a two –country, two firms model.

[11] We explore the open market impact on welfare in section 5.

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