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## Strategic Environmental Trade Policy Under Free Entry of Firms

by

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## Abstract

Since direct trade barriers are banned, governments may be tempted to (ab)use indirect trade-interfering policy tools, such as environmental taxes, to pursue their trade-managing aims. Using a model of an endogenous market structure where the number of firms is determined by a zero-profit condition in one country but is exogenously given in the other country, we show that the government harboring the fixed number of firms fails to affect aggregate supply and therefore has little scope for improving domestic environmental quality (if pollution is transboundary); moreover, due to the absence of the terms-of-trade effect, it diverts from the classical strategic tax rule. We argue that both governments 'very likely' fix their equilibrium emission taxes 'too low', meaning that tax competition plausibly leads to 'ecological dumping'.

# 1 Introduction

In the nineties the integration of the world economy has proceeded at an unprecedented rate. Yet, with the agreements to abolish tariffs and other direct trade barriers (e. g., European Single Market, NAFTA, GATT/WTO) indirect trade-interfering measures have emerged as potential instruments of trade policy. Among those one of the most justifiable and therefore a particularly popular vehicle is environmental policy. Governments wishing to manage trade may be tempted to (ab)use environmental instruments in order to pursue their trade-political objectives — and this temptation is even higher under imperfect competition in the goods markets.[1] The present paper takes up this point and aims at extending the contemporary literature on strategic trade policy with respect to this potential channel of indirect trade interference: environmental taxes.[2]

The second main feature of our paper is also attributed to the world economy's integration: The more the world economy becomes integrated, the more international financial capital is freely mobile and the easier financing new enterprises and building new market-influencing companies becomes. This leads to an increased tendency for mergers and takeovers, as recent evidence shows. (Hardly a week passes by in which we do not hear about any significant merger or takeover, or at least about a major strategic cooperation.) As a consequence, as markets become more integrated and trade becomes more brisk, market structures get vivid and are thus more likely to be subject to changes than before. For this reason we find that for many industries (computers, telecommunication, automobiles, banks, insurance companies, etc.) it is more appropriate to treat the number of incumbent firms as endogenous rather than as exogenous. But once there is free entry and exit of firms, the efficiency implications may be substantial — in particular for oligopolistic market structures. Combining both observations — the role of environmental policy as an indirect trade-policy tool and increasingly variable

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[1] Following the semantic of HORSTMAN AND MARKUSEN (1986) we may call this approach 'environmental (new) protectionism'.

[2] The need for scrutinizing the links between environmental and strategic trade policies has, among others, been emphasized by BRANDER (1995), p. 1450: '[...] the interaction between trade policies and environmental policies will become more important. [...] Accordingly, since many of the relevant industries are of the oligopoly type, it will be important to integrate resource and environmental concerns into models of strategic trade policy.'

international market structures — leads us to question: what does strategic policy look like, and to what extent and under which conditions may a government successfully pursue strategic trade policy by means of (WTO–conform) environmental tools when market structure is oligopolistic with free entry and exit?

Since the influential papers of BRANDER AND SPENCER (1981, 1985), DIXIT (1984), EATON AND GROSSMAN (1986), and others we know that when a country has some impact on the world-market price, *i. e.*, a country's aggregate supply represents a substantial part of world-supply, the government faces at least two incentives to interfere with trade: reducing competition among domestic firms in order to move them closer to the cartel-output level (terms-of-trade effect), and providing domestic firms with a strategic advantage to push the domestic industry's output closer to the Stackelberg-leader-output level (profit-shifting effect). In particular, when both foreign and domestic firms exclusively produce for a third country's market, each government has a rationale for subsidizing its firms as long as their market share is not 'too large';[3] and the larger their market share is, the more the government tends to reduce the subsidy — and finally the subsidy becomes a tax.

In recent years much work has been devoted to extending and generalizing the classical strategic-trade model in order to investigate the robustness of the results obtained in the earlier papers, cited above. For example, cost heterogeneity among firms from different countries has been scrutinized by DE MEZA (1986) and NEARY (1994); and among firms residing in the same country, by COLLIE (1993). The political economy of strategic trade policy has be investigated by MOORE AND SURANOVIC (1992) and others. (The list can easily be extended, however since it is not our intention to provide an overview here, which would drastically exceed the scope of this paper. The interested reader is therefore referred to the overview article of BRANDER, 1995.) Roughly summarizing these findings, it turns out that results are commonly not robust, neither with respect to technical assumptions nor with respect to the models' structures. So we must be reluctant to simply translate the results of contemporary trade literature onto strategic environmental policy problems in an international setting — in particular under free entry and exit.

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[3]This was pointed out by DIXIT (1984) and formally proved by KLETTE (1994).

Notably, environmentalists have drawn upon the trade literature and investigated whether and to what extent governments may engage in 'ecological dumping'.[4] Starting from the model of a large open economy with a competitive industry (MARKUSEN, 1975, and KRUTILLA, 1991), optimal strategic environmental policies have been investigated for non-competitive product markets: MARKUSEN, MOREY, AND OLEWILER (1993), (1995), MOTTA AND THISSE (1994), as well as RAUSCHER (1995) model the dependence of firms' location decisions on environmental policies. The consequences of different possible market structures for strategic environmental policies are analyzed within the 'third-country model': CONRAD (1993) and KENNEDY (1994) investigate strategic emission taxes in a two-country-duopoly model, and BAYINDIR-UPMANN (1998) generalizes this to the $n$-country case with heterogenous firms (and endogenous provision of public goods). Similarly, BARRETT (1994) analyzes the strategic choice of emission standards for different market structures, while ULPH (1992) asks what the optimal environmental policy instrument is under different modes of competition within a duopoly.

Surprisingly, in the environmental literature no one has, to the best of our knowledge, investigated strategic environmental policy when the number of incumbent oligopolists is *endogenous*;[5] in the trade literature, though, some authors have devoted their attention to oligopolistic markets with free entry and exit. Notable contributions are BRANDER AND KRUGMAN (1983), VENABLES (1985), HORSTMANN AND MARKUSEN (1986), MARKUSEN AND VENABLES (1988), and LAHIRI AND ONO (1995). But those authors focus on the welfare implications of opening the borders for free trade under free entry and exit of firms, and do not consider strategic policies (and the resulting Nash equilibria of these policy games).[6] Moreover, they do not investigate an integrated market for a homoge-

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[4]Following RAUSCHER (1994), p. 823, the phrase 'ecological dumping' does not mean price differentiation between home and abroad but '[...] a situation in which a government uses lax to support domestic firms in international markets.'

[5]Apart from strategic, trade-interfering aspects, we do find few contributions in the environmental literature dealing with free entry and exit in oligopolistic markets: REQUATE (1994) and KATSOULACOS AND XEPAPADEAS (1995) focus on optimal regulation, i. e., on optimal environmental policy for a *closed* economy.

[6]One exception is the contribution of JANEBA (1998) who focuses on equilibria of the 'locating game' — based on MARKUSEN, MOREY, AND OLEWILER (1993), (1995) — when firms'

nous product but separated markets and/or product differentiation.

In order to analyze to what extent governments may, when direct trade instruments are banned, (ab)use environmental instruments to pursue their trade-interfering targets and what the resulting welfare consequences are, we integrate strategic trade policy and environmental economics in one model. To reflect the dynamics of many markets within an (almost) integrated world economy, we endogenize the market structure by allowing for free market entry and exit within the framework of a Cournot oligopoly. Moreover, to be as general as possible, we avoid some of the limiting assumptions often imposed upon in the literature: segmented markets, pure export industry, constant marginal cost, and purely local pollution. Rather we model a single integrated world market with consumption in both trading countries, where firms use increasing-marginal-cost technologies (U-shaped average cost curves), and where pollution may be partially transboundary (with perfectly transboundary and purely local pollution as the limiting cases). The set-up of our model, just roughly described, is formally presented in Section 2.

The sequential structure of our model consists of three stages: In the first stage governments set their emission taxes; then, foreign firms decide about whether to enter the market or not (we assume that the number of firms at home is fixed, but firms may freely enter the market in 'the rest of the world'); and lastly, active firms engage in Cournot–competition. To calculate a subgame-perfect equilibrium of this game, we employ backwards induction: In Section 3 we derive the equilibrium of the Cournot game for any given numbers of firms and any given tuple of emission taxes. Then, in Section 4, we determine the equilibrium number of foreign firms, that number of firms which enter the market until all profit opportunities are eliminated. In Section 5 we carry out the comparative statics of the output market when governments alter their tax rates. We illuminate the asymmetry between the impact of the domestic and the foreign tax rate on the equilibrium of the good market. It is shown that, in contrast to the standard models with a fixed market structure, the domestic government can not affect world-wide aggregate output, although the home country's output represents a non-negligible part of the world supply (Proposition 5.1). On the contrary, the foreign government has, by means of its tax rate, a negative impact on aggregate

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locations are endogenous, but not their number.

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world supply; in addition, we show how the change of a foreign firm's optimal scale depends on the curvature of the demand curve (Proposition 5.2). Armed with these comparative static results, we derive the equilibrium emission taxes in Section 6 and contrast these with the second-best optimal tax rates. Section 7 summarizes the main results. Finally, in order to provide the reader with a basis for contrasting our results with the case where the market structure is fixed, we derive the equilibrium and second-best optimal tax rates for fixed numbers of firms in Appendix A. Some formal results are relegated to Appendix B.

# 2  The model

We consider two countries labeled 'home' and 'foreign' (or, alternatively, 'rest of the world'), in which $n \geq 1$ and $m \geq 1$ firms reside respectively. Firms are owned by those in whose jurisdiction they reside, that is, firms are located where their shareholders reside. All firms produce a single homogenous output good for a common, integrated world market. Within each country firms are assumed to use the same technology, but firms may differ across borders. We use lower and upper letters to denote the variables of the home and the foreign country respectively. Accordingly, let $q_1, \ldots, q_n$ and $Q_1, \ldots, Q_m$ represent the output quantities of the domestic and foreign firms; similarly, $y := \sum_{i=1}^n q_i$ and $Y := \sum_{i=1}^m Q_i$ denote aggregate output in both countries, respectively. Moreover, we use the convention $y_{-i} := y - q_i$ and $Y_{-i} := Y - Q_i$ to denote aggregate output in the home and the foreign country net of firm $i$'s output.

Production causes environmental damage, which we assume for simplicity to be proportional to output.[7] Normalizing emission quantities in both countries, each unit of output creates one unit of pollutant emissions: $e_i = q_i$, $\forall i = 1, \ldots, n$ and $E_i = Q_i$, $\forall i = 1, \ldots, m$. Moreover we use $e := \sum_{i=1}^n e_i$ and $E := \sum_{i=1}^n E_i$ to denote aggregate pollutant emissions in the home and the foreign country respectively. We allow for pollutants to be effective not only locally, but also abroad. Let $0 \leq \alpha \leq 1$ $[0 \leq \beta \leq 1]$ be the fraction of the foreign [home] country's pollu-

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[7]Implicitly we assume that no abatement technology exists. Clearly, this is a limiting assumption which one may wish to relax; yet, this would make the analysis much more tedious and probably would veil the clear-cut results obtained here.

tant emissions effective at home [abroad]. Then the effective levels of pollutants at home and abroad are given by $\bar{e} := e + \alpha E$ and $\tilde{E} := E + \beta e$, respectively — the levels on which environmental damage resulting from (international) pollutant transmission depends. More precisely, environmental damage at home and abroad can be represented by functions $d(\bar{e})$ and $D(\tilde{E})$, which we assume to be strictly increasing, (weakly) convex, and twice continuously differentiable.

Modeling an integrated market is assuming that the 'law of one price' holds. Then, aggregate world demand is given by the sum of both countries' demand functions (each of which is assumed to be decreasing), evaluated at the same price: $z = \tilde{z}(\phi) := \tilde{x}(\phi) + \tilde{X}(\phi)$, the inverse of which yields the inverse world demand curve: $p(z) := \tilde{z}^{-1}(z)$. Let $p^+ := p(0)$ denote the highest attainable price (choke-off price) — the price beyond which no demand exists — and let $z^+$ denote the potential size of the market — the smallest quantity which can only be 'sold' at a zero price: $p(z) > 0 \ \forall z \in [0, z^+)$ and $p(z) = 0 \ \forall z \geq z^+$. (Of course, $p^+$ and $z^+$ need not exist.) We assume that $p : \mathbb{R}_+ \to \mathbb{R}_+$ is continuously differentiable for all $z \in (0, z^+)$ and strictly decreasing over $[0, z^+]$. Moreover we make the following assumption.

**Assumption 2.1** *The elasticity of the inverse world demand curve exceeds minus unity:*

$$\frac{p''(z)}{p'(z)} z \ > \ -1 \qquad \forall z \in (0, z^+) \,.$$

Assumption 2.1 roughly says that the inverse world demand curve may not be 'too convex', which implies

$$p''(z)\check{z} + p'(z) \ < \ 0 \qquad \forall \ 0 < \check{z} \leq z < z^+ \,.$$

In the absence of emission charges, each firm's cost is the sum of some fixed non-negative cost $f$ $[F]$ and variable production cost $c : \mathbb{R}_+ \to \mathbb{R}_+ : q_i \mapsto c(q_i)$ [and similarly for $C(Q_i)$]. We assume variable cost to be twice continuously differentiable for $z^+ \geq q_i \geq 0$ $[z^+ \geq Q_i \geq 0]$; moreover,

**Assumption 2.2**

1. *variable cost is strictly increasing and (weakly) convex: $c' > 0$ and $c'' \geq 0$, $\forall q_i \in [0, z^+]$, [and similarly for $C(Q_i)$];*

2. *the minimal average cost satisfy:* $\min\{(c(q_i^-) + f)/q_i^-, (C(Q_i^-) + F)/Q_i^-\} < \min\{p(q_i^-), p(Q_i^-)\}$, *where* $q_i^- := \arg\min_{q_i}(c(q_i) + f)/q_i$, *[and similarly for* $Q_i^-$ *];*

Part 1 of Assumption 2.2 ensures that average cost curves are $\cup$-shaped, provided that $c$ is strictly convex; if marginal cost are constant, $c'' = 0$, firms face an increasing-returns-to-scale technology. Part 2 guarantees that a market exists: In the absence of taxation, when firms produce at their cost-minimizing scales, production is profitable, for at least one firm.

In order to mitigate industrial pollutant emissions and thus to protect environmental quality, governments in both countries are free to choose emission charges per unit of pollutant emissions, $t$ [and $T$]. However, since emission charges also increase a firm's cost by $te_i$ [$TE_i$], environmental policy also affects each firms competitive position on the world market. Therefore, a government considering an increase of its emission charge weighs the trade off between an improvement of environmental quality and domestic firms' higher profits, which are paid to residents as dividend income. To be able to weigh both effects, we must specify welfare. Abstracting from income effects, the residents' welfare in the home country is the sum of consumer surplus, profits, and tax revenue, net of social damage resulting from pollutant emissions:

$$\int_0^x p^H(\xi)d\xi - p(z)x + p(z)y - \sum_{i=1}^n c(q_i) - nf - d(y + \alpha Y), \qquad (1)$$

where $p^H$ denotes the inverse demand curve in the home country and $z := y + Y$ represents aggregate production. [And similarly for welfare in the foreign country.]

When determining its emission tax, a government maximizes, for any given foreign tax, its residents' welfare taking into account the impact of its policy on the equilibrium of the output market. Formally, we deal with a game where in the first stage governments play a game in tax rates, in the second stage firms decide whether to enter the market or not, and in the third stage active firms engage in Cournot competition. We are interested in the subgame-perfect equilibrium of this game. To obtain the equilibrium tax rates of both governments, we solve the game by backward induction: First, we ask how the equilibrium on the output market looks like for any fixed number of domestic firms (and any given tuple of

emissions taxes in both countries); second, we investigate how many firms enter the market for any given values of $t$ and $T$, when, after entrance-decisions are made, the Nash equilibrium on the output market results; and third, we show how governments, knowing firms' decisions at the subsequent stages, choose their tax rates in equilibrium.

# 3 Third stage: equilibrium on the output market

Given any emission taxes $t$ and $T$ and any numbers of competitors, $n$ and $m$, each firm maximizes its profit for any given output decisions of its rivals. That is, firm $i$ maximizes

$$\pi(q_i, y_{-i} + Y) = p(z)q_i - \underbrace{(c(q_i) + tq_i + f)}_{=:\mathfrak{c}}$$

with respect to $q_i$, respectively

$$\Pi(Q_i, Y_{-i} + y) = p(z)Q_i - \underbrace{(C(Q_i) + TQ_i + F)}_{=:\mathfrak{C}}$$

with respect to $Q_i$, where we have used $z := y + Y = q_i + y_{-i} + Q_i + Y_{-i}$, $e_i = q_i$ and $E_i = Q_i$. ($\mathfrak{c}$ and $\mathfrak{C}$ denote total cost including taxes.) Since within each country firms are symmetric, Assumptions 2.1 and 2.2 ensure that the equilibrium output decisions among firms of the same jurisdiction are identical. Then, for any fixed pair of numbers of firms, the Cournot-equilibrium of the output market is characterized by

$$p'(z^c)q^c + p(z^c) - c'(q^c) - t = 0, \tag{2}$$

$$p'(z^c)Q^c + p(z^c) - C'(Q^c) - T = 0, \tag{3}$$

$$nq^c + mQ^c = z^c. \tag{4}$$

where $q^c := y^c/n$ and $Q^c := Y^c/m$ denote firms' equilibrium output levels. Let $\sigma := zp'(z)/p(z)$ denote the elasticity of the inverse demand curve and $\mathfrak{mc}$ and $\mathfrak{MC}$ represent total tax-inclusive marginal cost. Using this definition we obtain from equations (2) and (3)

$$\frac{(p^c - \mathfrak{mc}^c)/p^c}{q^c/z^c} = -\sigma^c = \frac{(p^c - \mathfrak{MC}^c)/p^c}{Q^c/z^c}.$$

That is, firms in both countries adjust their supply so as to equate (the absolute value of) the elasticity of the inverse demand curve with their mark-up over marginal cost divided by their market share.

# 4 Second stage: equilibrium number of firms

Suppose that the number of firms in the foreign country, $m$, is endogenous, while the number of domestic firms, $n$, is fixed. — One can think of a government which is able to control, i. e., to keep fixed, the number of domestic firms, while the number of firms in the 'rest of the world' is variable so as to eliminate profit opportunities.[8] — Then (slightly abusing notation) the equilibrium number of firms in the rest of the world $m^c$ is determined according to

$$p(z^c)Q^c - C(Q^c) - F - TQ^c = 0.\qquad(5)$$

Thus, $m^c$ is the maximal number of foreign firms which can, given the number of domestic firms, survive in equilibrium, i. e., obtain a non-negative profit. From equation (5) it follows that foreign firms enter the market until price equals average cost: $p = \mathfrak{C}/Q =: \mathfrak{AC}$. Inserting this into equations (2) and (3) yields[9]

$$-\frac{\mathfrak{AC} - mc}{q} = p' = -\frac{\mathfrak{AC} - \mathfrak{MC}}{Q},$$

from which it follows that

$$Q > q \quad \Leftrightarrow \quad \mathfrak{MC} < mc.$$

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[8]Of course, considering the case where $n$ and $m$ are endogenous is not of much interest — not to say, doesn't make sense. In this case, any profits were eliminated implying that for firms in both countries we have 'price equal average costs'. As long as average costs of domestic and foreign firms differ, only the lower average-cost firms can survive, and thus total concentration of production in one countries results. Only in the special case where evaluated at (2) and (3) average costs at home and abroad are equal, are firms able to survive in both countries; but then, of course, the resulting numbers $n$ and $m$ were not unique, and, moreover, this cannot occur in tax-equilibrium since any tax reduction (subsidy increase) would drive all the competing country's firms out of the market.

[9]For simplicity, we omit the upper index 'c' in the subsequent analysis, and correspondingly suppress the adjective 'equilibrium' relating to 'output', 'number' etc.

Those firms exhibiting the lower marginal cost, including emission taxes, produce a higher output. If marginal cost are equal for firms in both countries, all firms produce at the same scale, i. e., they are, in terms of output, of equal size.

# 5  Comparative statics

We now pursue comparative statics which provides us with the basis for the derivation of the equilibrium tax rates. We show that the domestic government is incapable of affecting aggregate output, and hence the world-market price and consumer surplus in both countries are unaffected by $t$. Moreover, as constant aggregate output also implies that aggregate pollutant emissions remain constant, the domestic government only succeeds in improving regional environmental quality when pollution is not perfectly transboundary. The foreign government, on the other hand, has a negative impact on aggregate supply and therefore, in determining its equilibrium tax, takes into account the well-known terms-of-trade effect — which vanishes for the home region. Whether a higher emission tax improves environmental quality, depends on the extent of international pollutant transmission.

## 5.1  The effects of an increase in the domestic tax

The equilibrium of the output market is determined by firms' first-order conditions (2) and (3), the supply identity (4) and the zero-profit condition (5), all of which are evaluated at $m = m^c$. Differentiating these equations with respect to $t$ and solving for the desired derivatives yields

$$\frac{\partial q}{\partial t} = \frac{1}{p' - c''} < 0 , \tag{6}$$

$$\frac{\partial y}{\partial t} = \frac{n}{p' - c''} < 0 , \tag{7}$$

$$\frac{\partial Q}{\partial t} = 0 , \tag{8}$$

$$\frac{\partial m}{\partial t} = -\frac{n}{Q(p' - c'')} > 0 , \tag{9}$$

$$\frac{\partial Y}{\partial t} = -\frac{n}{p' - c''} > 0 , \tag{10}$$

$$\frac{\partial z}{\partial t} = 0. \tag{11}$$

We summarize these results in the following proposition.

**Proposition 5.1** *When the number of firms in the home country is fixed, while the number of foreign firms is endogenous, an increase in the domestic emission tax*

1. *leads to a decrease in each domestic firm's output and thus*

2. *to a decrease of aggregate domestic output;*

3. *has no effect on per-firm output abroad;*

4. *but increases the number of foreign firms,*

5. *such that world-wide output remains constant, and so do aggregate pollutant emissions.*

Although the government in the home country is able to reduce domestic environmentally harmful production, aggregate production and hence aggregate pollutant emissions remain constant world-wide. When production is reduced in the home country, implying that *ceteris paribus* the world-market price goes up, profit opportunities emerge which provoke the entrance of new firms abroad. In order to exploit profit opportunities totally, the entrance of foreign firms continues until the increase in foreign aggregate production exactly offsets the shrink in domestic firms' supply. Finally, aggregate world-wide production remains constant and so does the market price. With a constant market price a foreign firm's optimal output level remains also constant and any increase in foreign supply is exclusively achieved through the entrance of new firms. As a result, the domestic government is unable to affect the world-market price and thus consumer surplus, and it only succeeds in improving domestic environmental quality when there is, at least, incomplete pollutant transmission; while in the polar case when local pollutant emissions are instantaneously effective globally, domestic environmental policy completely fails to affect environmental quality, at home as well as abroad. In this case, does unilateral environmental policy not have any effect either on consumer surplus or on environmental quality.

This is a remarkably negative result in a two fold sense. First, one might hope for reducing *aggregate* pollutant emissions, when one country — or even one group of countries — tightens its emission taxes. Yet, our results show that such a unilateral policy fails to affect world-wide pollutant emissions when there is free market entrance in, at least, one other country. And second, a single government even fails to improve *national* environmental quality, when pollutants are perfectly transboundary. But on the other hand there is also a beneficial effect to consumers: The price does not increase as the government tightens its tax screw. Thus, firms fail to succeed in cost shifting.

## 5.2 The effects of an increase in the foreign tax

In view of the preceding result, the question arises how environmental quality and the goods market are affected when the foreign country (the rest of the world) tightens its environmental policy. To see this, differentiate equations (2), (3), (4), and (5) with respect to $T$, yielding

$$\frac{\partial Q}{\partial T} = -\frac{p''Q}{p'\Lambda}, \tag{12}$$

$$\frac{\partial m}{\partial T} = \frac{(p'-c'')(2p'+mp''Q-C''')+n(p'+p''q)(2p'-C''')}{p'Q(p'-c'')\Lambda} < 0, \tag{13}$$

$$\frac{\partial Y}{\partial T} = \frac{(p'-c'')(2p'-C''')+n(p'+p''q)(2p'-C''')}{p'(p'-c'')\Lambda} < 0, \tag{14}$$

$$\frac{\partial q}{\partial T} = -\frac{(p'+p''q)(2p'-C''')}{p'(p'-c'')\Lambda} > 0, \tag{15}$$

$$\frac{\partial y}{\partial T} = -\frac{n(p'+p''q)(2p'-C''')}{p'(p'-c'')\Lambda} > 0, \tag{16}$$

$$\frac{\partial z}{\partial T} = \frac{2p'-C'''}{p'\Lambda} < 0, \tag{17}$$

where $\Lambda := 2p' + p''Q - C''' < 0$.

We summarize these results in the following proposition:

**Proposition 5.2** *When the number of firms in the home country is fixed, while the number of foreign firms is endogenous, an increase in the foreign emission tax*

1. *leads to an increase (decrease) of each foreign firm's output if, and only if, the inverse demand curve is concave (convex);*

2. *depresses the number of foreign firms;*

3. *reduces aggregate foreign production;*

4. *encourages domestic firms' production; and*

5. *makes aggregate world-wide output and hence aggregate pollution fall.*

As before $y$ and $Y$ move in opposite directions, but, contrary to the effect of an increase of $t$, here aggregate production falls, implying that the price rises and consumers in both countries are worse off. Moreover, it follows that foreign environmental quality improves, while the effect on domestic environmental quality depends on the extent to which foreign pollutant emissions are effective at home: If pollution is purely local, domestic environmental quality deteriorates, since $y$ increases; if pollution is completely transboundary, environmental quality improves, since $z$ decreases; and for incomplete pollutant transmission the effect must be in between.

The intuition behind our results is straightforward — except perhaps for the dependence of per-foreign-firm's output on $T$. It might seem puzzling that $Q$ does not unambiguously fall (which naturally occurs when $m$ is fixed and firms are identical; confer Appendix A), rather a foreign firm's supply depends on the curvature of the (inverse) demand curve. Within a framework of a fixed number of heterogenous firms it has been recognized before that optimal (strategic) taxes/tariffs depend upon the curvature of the demand curve under imperfect competition (see, for example, BRANDER AND SPENCER, 1984; JONES, 1987; and BANDYOPADHYAY, 1997). Yet, this dependency holds true even if we abstract from trade aspects as do for example LEVIN (1985) and VAN LONG AND SOUBEYRAN (1997): depending on the curvature of the demand curve stricter tax policies may make some firms increase their output while total output decreases.[10] The driving force therein is simply the asymmetry between firms, an effect which

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[10]Loosely speaking, they found that large firms (relatively) benefit when the inverse demand curve is concave, and lose otherwise. Thus, allocative production efficiency is lower for a convex demand curve.
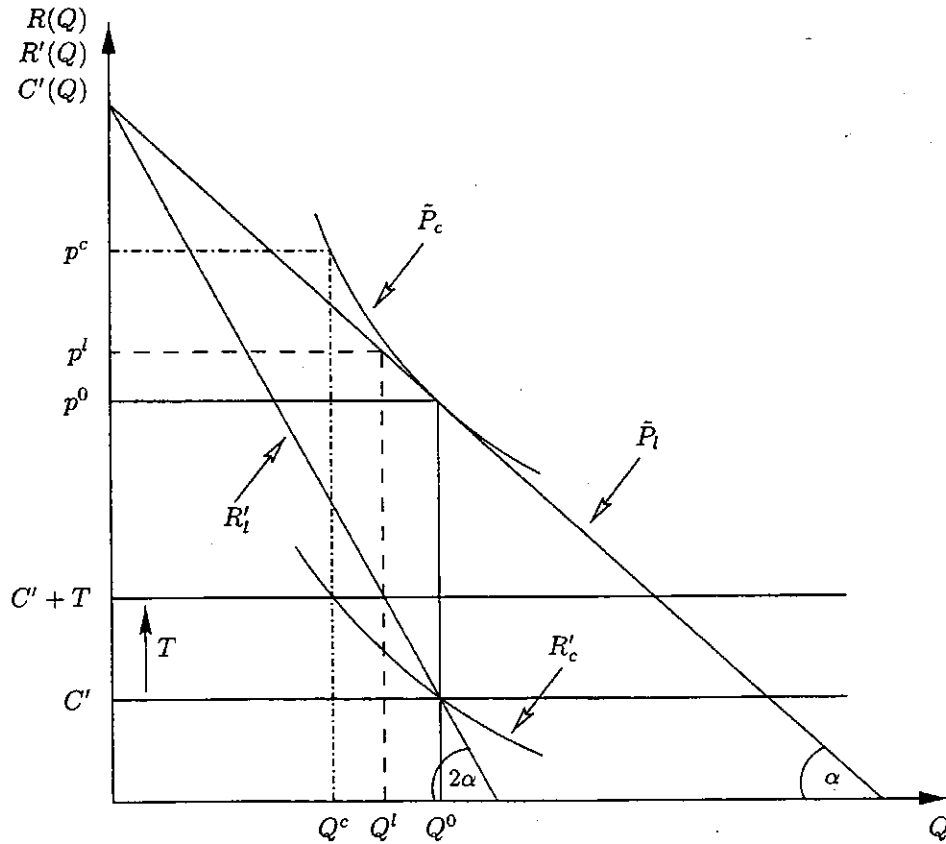
Figure 1: *The impact of the curvature of the inverse demand curve on a firm's output change*

is absent here, for firms liable to the same tax rate are assumed to be symmetric. Because little intuition is provided in the literature for the dependence of the comparative statics results on the curvature of the demand curve,[11] we rest here for a moment devoting some lines to provide the reader with an intuition for this phenomenon.

Consider a firm's profit-maximization problem. Each firm equates marginal revenue $(R')$ and marginal cost $(\mathfrak{MC} = C' + T)$. When marginal cost increase, the induced change of equilibrium marginal revenue equals $p''(z)Qdz + p'(z)\,(dQ + dz)$. Since each firm takes $z - Q$ as given, the anticipated marginal change of marginal revenue equals $p''(z)Q + 2p'(z)$. Hence, for any given slope of the inverse demand curve, $p'$, marginal revenue falls by less as $p''$ increases. To illustrate this, consider

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[11]Within the framework of a one-country model REQUATE (1997), p. 269, formally recognizes: 'Surprisingly, however, individual output *decreases* if inverse demand is strictly *convex*, it *increases* if inverse demand is strictly *concave*, and it is *constant* for *linear* demand'.

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Figure 1. Therein we draw the residual demand curve for a firm which faces an affine-linear inverse demand curve (the $\tilde{P}_l$-curve) with slope $-s = \tan\alpha$, implying that the marginal revenue curve ($R'_l(Q)$) is affine-linear with slope $-2s$. In this case, any increase in marginal cost (from $C'$ to $C' + T$) leads, *ceteris paribus*, to a marginal reduction of $Q$ by $1/(2s)$ (from $Q^0$ to $Q^l$). Compare this with the case when, for given values of $z$ and $p'(z)$, the inverse demand curve becomes (locally) strictly convex (the $\tilde{P}_c$-curve in Figure 1). In this case, any output reduction leads to a more drastic increase in price which mitigates the negative consequences of a cost increase for the firm. Hence, marginal revenue falls more slowly compared with the linear case, implying that the opportunity costs of an output reduction (in terms of forgiven revenue) are lower as, *ceteris paribus*, the demand curve becomes more convex. As a consequence, the more convex the inverse demand curve is, the more each firm 'voluntarily' reduces/increases its output when marginal cost increase/decrease (from $Q^0$ to $Q^c$). And the reverse line of arguments holds for a concave demand curve. This effect, in turn, mitigates the induced exit of foreign firms: Under rather mild conditions, the exit of firms is the lower, the higher $p''$ is.[12] In other words, the more convex (less concave) the demand curve is, the less drastic the concentration process triggered off by a higher foreign tax rate is. Similarly, the induced increase in the domestic firms' supply is lower and the reduction of aggregate (world) supply is more drastic as the demand curve becomes more convex. In sum, the curvature of the demand curve represents an important determinant for the response of firms' supply-, entry- and exit-decisions and therefore is an important factor of the concentration process induced by higher (environmental) tax rates.

# 6   First stage: equilibrium in emission taxes

Now we are prepared for deducing the equilibrium tax rates, more precisely the subgame-perfect tax rates. Inserting our previous results into both countries' welfare functions yields (reduced) welfare functions which depend on $t$ and $T$

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[12]Formal results are provided in Appendix B.

exclusively. Slightly abusing notation, we obtain

$$w(t,T) := \int_0^{x(t,T)} p^H(\xi)\,d\xi - p(z(t,T))\,x(t,T) - d\,(y(t,T) + \alpha Y(t,T))$$
$$+ p(z(t,T))\,y(t,T) - n\,c(q(t,T)) - nf\,, \tag{18}$$

and similarly for the foreign country.

Suppose that each government chooses, for any given tax of the competing country, its tax rate so as to maximize its residents' welfare. That is, the domestic and the foreign government set their respective taxes according to $\partial w(t,\bar{T})/\partial t = 0 \ \forall \bar{T} > 0$ and $\partial W(\bar{t},T)/\partial T = 0 \ \forall \bar{t} > 0$. Omitting arguments we obtain the following equations

$$(y - x)p'\frac{\partial z}{\partial t} + pn\frac{\partial q}{\partial t} - nc'\frac{\partial q}{\partial t} = \left(\frac{\partial y}{\partial t} + \alpha\frac{\partial Y}{\partial t}\right) d'\,,$$

$$(Y - X)p'\frac{\partial z}{\partial T} + p\frac{\partial Y}{\partial T} - (C + F)\frac{\partial m}{\partial T} - mC'\frac{\partial Q}{\partial T} = \left(\frac{\partial Y}{\partial T} + \beta\frac{\partial y}{\partial T}\right) D'\,.$$

where $\frac{\partial Y}{\partial T} = \left(Q\frac{\partial m}{\partial T} + m\frac{\partial Q}{\partial T}\right)$. Applying the first order conditions (2) and (3) and the zero-profit condition (5), we can 'solve' each equation for the respective tax rate:

$$\hat{t} = (1 - \alpha)d' + qp'\,, \tag{19}$$

$$\hat{T} = (1 + \beta y')D' - (Y - X)(1 + y')p' + \frac{m\,\partial Q/\partial T}{\partial Y/\partial T}Qp'\,, \tag{20}$$

where we have defined $Y' := \frac{\partial Y}{\partial t} \big/ \frac{\partial y}{\partial t} = -1$ and $y' := \frac{\partial y}{\partial T} \big/ \frac{\partial Y}{\partial T} \in (-1,0)$. Equations (19) and (20) characterize the best response curves for the domestic and foreign government respectively, the intersection of which gives us the equilibrium tax rates. Again slightly abusing notation, we can speak of $\hat{t}$ and $\hat{T}$ as the equilibrium tax rates. Those consist of two respectively three terms: The first terms reflect the marginal impact of an unilateral increase of a local emission tax on the country's environmental quality. When pollution is purely local ($\alpha = 0 = \beta$), environmental quality improves to the extent to which local firms reduce their emissions, and the marginal environmental benefit were equal to $d'$ [$D'$]. Yet, since firms of the other country increase their output (cf. eqs (10) and (16)), a counteracting effect is triggered off tending to reduce the actual environmental benefit, as long as pollutants are at least partially transboundary ($\alpha, \beta > 0$). This effect

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reducing the local benefit from emissions taxation is the stronger, the more pollution is transboundary and the more foreign firms respond to a given reduction of domestic supply by increasing their output — and is therefore maximal for the home country since $Y' = -1$, whereas $-1 < y' < 0$. Conversely, if pollutants are primarily a local problem, governments tend, *ceteris paribus*, to shift pollution outwards by means of higher emission taxes, for the total environmental benefit induced by this policy is higher the lower $\alpha$ [$\beta$] is. This is what is sometimes called the 'not-in-my-backyard' incentive (see, for example, MARKUSEN, MOREY AND OLEWILER, 1995).

The second term of $\hat{T}$, equation (20), reflects the extent to which local residents benefit from a change in aggregate output. As they are consumers, they benefit from a lower price, so the equilibrium tax will be the lower the higher domestic demand is. However, as residents are also local firms' shareholders, they benefit from higher profits and therefore from a higher output price. The latter effect dominates the first when the country is a net-exporter, but it falls short of the first when the country is a net-importer. This phenomenon, well recognized in the literature, is called *terms-of-trade effect* (see, for example, BRANDER AND SPENCER, 1985). If no other effects were present, the equilibrium tax rate of a net-exporting (-importing) region would exceed (fall short of) local marginal damage. Note that a terms-of-trade effect does not appear in the formula for $\hat{t}$, equation (19), for $z$ does not change as the domestic government alters its emission tax, (see equation (11)). That is, independent of its actual trade position, the domestic government behaves as if net-exports were equal to zero (settled trade-balance). This is at variance with models of exogenously given market structures where a terms-of-trade effect is generally present — even under perfect competition (see, for example, KRUTILLA, 1991, p. 131, eq. 13). Thus, free market entry lets the terms-of-trade motive vanish for the domestic country — an effect which has, to the best of our knowledge, not been recognized previously.

Because the last terms of $\hat{t}$ and $\hat{T}$ do not appear for a competitive industry, they stem from imperfect competition. This imperfect-competition effect[13]

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[13]In the literature, the imperfect-competition effect is often called 'profit-shifting effect' (see, for example, BRANDER, 1995, p. 1409). We find this somewhat misleading, for the terms-of-trade effect also reflects the government's incentive to increase domestic industry's aggregate profit, while the second effect can unambiguously attributed to imperfect competition.

exactly reflects the extent to which the strategic tax must be reduced when aggregate output is, due to imperfect competition among domestic firms, lower than it would have been under perfect competition. In other words, ignoring the imperfect-competition effect, the strategic tax were to high and output would be reduced by too large an amount, for non-competitive firms have, compared with the competitive case, already reduced their output 'voluntarily'. Therefore, the strategic tax must be reduced — and may eventually even become negative. As a consequence, for an export industry the imperfect-competition effect; *ceteris paribus*, counteracts the terms-of-trade effect, and EATON AND GROSSMAN (1986) have shown that for an international duopoly with pure exports (third-country model) the imperfect-competition effect dominates the terms-of-trade effect leading to a subsidization equilibrium: each governments provides its firm with a strategic cost-advantage in order to make it behave like a von Stackelberg leader.

This output-increasing motive is particularly strong for the domestic government, for under free entry the foreign industry responds to a domestic output increase by reducing its output such that world-wide supply remains constant $(\partial z/\partial t = 0)$. The domestic government seeks to make resident firms behave as if they were perfectly competitive. (The terms-of-trade effect is completely absent.) In this sense, the free-entry formula for the domestic government, equation (19), represents a polar case of the classical trade literature. Note that the reason for the domestic government to subsidize production is not its concern about too low a consumer surplus — $z$ and therefore $p$ is fixed — but to make the profit-shifting-effect most effective. (Analogously, the domestic government's subsidy is lower than it would be in the classical model with domestic consumption for a net-importing country.)

To investigate the last term of the formula for $\hat{T}$ thoroughly, let $\epsilon := \frac{Q}{m}\frac{\partial m/\partial T}{\partial Q/\partial T}$ denote the relative change of the number of firms to the change of output per firm (the ratio of cost elasticities of $m$ and $Q$). Using this definition we can write[14]

$$\frac{\partial Q/\partial T}{\partial Y/\partial T} = \frac{\partial Q/\partial T}{m(\partial Q/\partial T) + Q(\partial m/\partial T)} = \frac{1}{m(1+\epsilon)} < \frac{1}{m}.$$

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[14]The inequality can be shown as follows. Since $\partial Y/\partial T < 0$, $\epsilon$ must either fall short of $-1$ (if $\partial Q/\partial T > 0$) or be positive (if $\partial Q/\partial T < 0$), which follows from $\partial m/\partial T < 0$. Thus, $\epsilon \notin [-1, 0]$ implying that $(\partial Q/\partial T)/(\partial Y/\partial T) < 1/m$.

In the limiting case where $m$ is fixed ($\epsilon = 0$), $\frac{\partial Q/\partial T}{\partial Y/\partial T}$ equals $1/m$ implying that the change of $Y$ would coincide with the sum of all individual output changes. In this case the last term of at the right-hand side of equation (20) would reduce to $\frac{1}{m}Yp' = Qp'$, which were exactly symmetric to the last term of $\hat{t}$. If in addition $y'$ were equal to $-1$ (as does $Y'$), then $\hat{t}$ and $\hat{T}$ would be perfectly symmetric.

## Second-best-efficient tax rates

For further scrutinizing the equilibrium tax rates it is helpful to compare them with the second-best-efficient tax rates, given by[15]

$$t^* = d' + \beta D' + qp' + \frac{m\partial Q/\partial T}{\partial z/\partial T}Qp', \tag{21}$$

$$T^* = D' + \alpha d' + \frac{m\partial Q/\partial T}{\partial z/\partial T}Qp'. \tag{22}$$

These tax rates account for environmental externalities caused at home and abroad as well as for the consequences of imperfect competition on the output market and reflect the asymmetry in the market structure between both countries. Therein the term $\frac{\partial Q/\partial T}{\partial z/\partial T}$ reflects the shift of market shares as $T$ increases. It can be shown that each foreign firm's market share, $Q/z$, must fall as the foreign tax rises. Note that if the environmental terms are identical $d' + \beta D' = D' + \alpha d'$, $\hat{t}$ must fall short of $\hat{T}$, reflecting the fact that competition is less tough among domestic firms than among foreign firms.

Comparing equations (19) and (20) with (21) and (22) it becomes clear which effects governments neglect when determining their *equilibrium* tax rates: Firstly, they ignore environmental externalities, but take into account induced environmental 'feed-back' effects resulting from international pollutant transmission. Secondly, they try to use their tax rates strategically in order to affect the world-market price to the benefit of their residents, which depends on the nation's trade position. Yet, for the domestic country this is not a source of inefficiency: the $qp'$–term reflecting the governments endeavor to increase production is welfare increasing due to imperfect competition, and consequently it appears in both

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[15]$t^*$ and $T^*$ can be obtained by maximizing the sum of both countries welfare with respect to $t$ and $T$ simultaneously and 'solving' the result for both tax rates. The derivation is left out here in order to save space, but can be obtained from the author upon request.

formulae (equations (19) and (21)) — though for different reasons. For the foreign tax rate this term hinges on the endogeneity of $m$ — which represents the third effect. Since, as argued above, foreign firms adjust their output decisions in accordance with the curvature of the demand curve, the government must adjust its equilibrium tax accordingly: the more each firm reduces its scale (the more convex the inverse demand curve is), and therefore the less the number of active firms falls, the lower the tax rate is the government levies. Under efficient taxation, both governments have to take into account the endogeneity of $m$. And thus the curvature of the inverse demand curve is irrelevant for the optimal *differentiation* of the emission taxes (the last terms in (21) and (22) are identical). Note that only for an affine-linear demand curve, where $\partial Q/\partial T$ equals zero, these terms disappear — in all formulae.

## Welfare analysis

Finally, one might question whether the equilibrium tax rates are two low or possibly too high from an efficiency point of view. Since formulae (19) and (20), on the one hand, and (21) and (22), on the other hand, are evaluated at different allocations, a comparison of both tax vectors is a delicate task, and can therefore only be done accurately for concrete numerical examples. However, we can ask what happens to both countries' welfare if we raise both equilibrium tax rates by infinitesimal amounts. That is, what are the signs of the total derivatives of $w(\hat{t}, \hat{T})$ and $W(\hat{t}, \hat{T})$ if we increase both tax rates slightly by $dt$ and $dT$. First, consider domestic welfare. Since $\partial w(\hat{t}, \hat{T})/\partial t$ equals zero, we have

$$dw = \frac{\partial w(\hat{t}, \hat{T})}{\partial T} dT = -\frac{\partial z}{\partial T} \left[-(y-x)p' + \alpha d'\right] dT.$$

It follows that

$$dw > 0 \quad \Leftrightarrow \quad \underbrace{-\frac{\alpha d'}{p'}}_{>0} > x - y. \tag{23}$$

Condition (23) shows that if the net-imports of the domestic country are 'not too large', a small increase in both tax rates is, evaluated at the tax-equilibrium, beneficial for the domestic country.

Similarly,

$$dW = \frac{\partial W(\hat{t}, \hat{T})}{\partial t} dt = -\underbrace{\frac{\partial Y}{\partial t}(1+y')}_{>0} [-(Y-X)p' + \beta D'] + \frac{\partial Q/\partial T}{\partial Y/\partial T} \underbrace{\frac{\partial Y}{\partial t}}_{<0} Yp' \, dt.$$

It follows that if the inverse demand curve is (weakly) concave, it is sufficient for $dW > 0$ that

$$\underbrace{-\frac{\alpha D'}{p'}}_{>0} > X - Y. \qquad (24)$$

Similarly to condition (23), condition (24) shows that if foreign net-imports are 'not too large', a small increase in both tax rates is also beneficial for the foreign country. This positive effect is the more 'likely' the more concave (less convex) the demand curve is. In sum, there are good reasons to argue that the equilibrium tax rates are 'too low', provided that neither $p''$ is 'too large' (note that $p''$ is already restricted from above by Assumption 2.1) nor the trade-deficit for the importing country is 'too substantial'. Under these conditions, which we do not find to be unplausible in general, strategic trade policies in emission taxes lead to too low environmental levies (too lax environmental standards). Thus, we may conclude that, in this sense, environmental tax competition plausibly leads to 'ecological dumping'.

# 7 Conclusion

As direct trade policies have been banned in the course of intensified world-wide economic integration, a closer investigation of WTO–conform, indirect trade-policy instruments is required. The present paper aims at contributing to this topic: We have extended the literature of strategic trade policy by integrating taxation of environmentally harmful pollutant emissions and international trade policies when the number of firms is endogenous and direct trade instruments are not available.

We assumed that, within an integrated world-market where the supply side is oligopolistic, market entry and exit is restricted in one country (home country) but that firms can freely enter and leave the market in the other country

(rest of the world). We obtained a couple of remarkable results, the most important of which are the following. Firstly, the asymmetry assumption of the market structure between both countries results in an incapability of the domestic government to affect aggregate production and hence the world-market price and world-wide pollutant emissions. As a consequence, when there is free market entry abroad, a government has a strong incentive (apart from environmental aspects) to subsidize domestic production for strategic reasons: firms are subsidized in order to make them behave as if they faced a perfectly competitive environment. This result stands in contrast to the classical third-country model with an exogenously given market structure (duopoly model) in which the domestic firm is subsidized to make it behave as if it were a von Stackelberg leader. As a corollary of the constant-output result, we obtain secondly: as long as pollution is not purely a local problem, the extent to which the domestic government can improve national environmental quality is rather limited and even drops to nil if pollution is perfectly transboundary. Thirdly, we have illustrated that each foreign firm's output-change in response to a cost-increase crucially depends on the curvature of the demand curve, which therefore is an important determinant of market-concentration/-monopolization. And fourthly, though we can not prove that governments set their equilibrium emission taxes 'too low' in general, we find that there are good reasons to presume that this will occur 'most likely' in equilibrium, and in this sense environmental tax competition plausibly leads to 'ecological dumping'.

A couple of questions though remained open and are left for future research. For example, it is interesting to scrutinize the robustness of our results when firms possess abatement technologies; the introduction of (reasonable) transportation costs, which allows for endogenizing the number of domestic firms, might also be challenging; and lastly, embedding this approach into a political-economy model seems to be another fruitful direction for future research.

# Appendix A: A fixed number of firms in both countries

In order to provide the reader with some further insight in and intuition for our results obtained in the main text, we derive the corresponding formulae when the numbers of firms are *fixed in both countries*. This allows for a better understanding of the effects of endogenizing the number of foreign firms. To obtain the comparative statics results, differentiate for fixed values of $m$ and $n$ the first-order conditions (2) and (3) and the supply identity with respect to $t$, yielding

$$\frac{\partial q}{\partial t} = \frac{p' - C'' + m(p' + Qp'')}{\Theta} < 0, \qquad (A.1)$$

$$\frac{\partial y}{\partial t} = n\frac{\partial q}{\partial t} < 0, \qquad (A.2)$$

$$\frac{\partial Q}{\partial t} = -\frac{n(p' + Qp'')}{\Theta} > 0, \qquad (A.3)$$

$$\frac{\partial Y}{\partial t} = m\frac{\partial Q}{\partial t} > 0, \qquad (A.4)$$

$$\frac{\partial z}{\partial t} = \frac{n(p' - C'')}{\Theta} < 0 \qquad (A.5)$$

and symmetrically for the effects of $T$, where $\Theta := (p' - c'' + n(p' + qp'')) (p' - C'') + m(p' + Qp'')(p' - c'') > 0$.

Using these results and carrying out the same steps as before, we can derive the equilibrium tax rates of both governments:[16]

$$\hat{t}_{\bar{m}} = (1 + \alpha Y')d' - (y - x)(1 + Y')p' + \frac{1}{n}yp', \qquad (A.6)$$

$$\hat{T}_{\bar{m}} = (1 + \beta y')D' - (Y - X)(1 + y')p' + \frac{1}{m}Yp', \qquad (A.7)$$

where $Y' := \frac{\partial Y}{\partial t} / \frac{\partial y}{\partial t}$, $y' := \frac{\partial y}{\partial T} / \frac{\partial Y}{\partial T}$, with $Y'$ and $y' \in (-1, 0)$. The interpretation of the equilibrium taxes, given by (A.6) and (A.7), is analogous to that provided for $\hat{t}$ and $\hat{T}$, confer eqs (19) and (20): The first term represents the environmental effect; the second, the terms-of-trade effect; and the third, the imperfect-competition effect, all of which are strategically motivated.

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[16]Setting $d' = D' = 0$, *i. e.*, ignoring environmental aspects, and evaluating eqs (A.6) and (A.7) at $n = m = 1$, $\hat{t}_{\bar{m}}$ and $\hat{T}_{\bar{m}}$ reduce to the formula given by BRANDER AND SPENCER (1985), eq. (28) therein; and similarly for $t_{\bar{m}}^*$ and $T_{\bar{m}}^*$ (as defined in (A.8) and (A.9)), cf. eq (32) in their article.

Obviously, the Nash equilibrium is inefficient, and the second-best efficient allocation can be induced by the tax rates

$$t_{\bar{m}}^* = d' + \beta D' + \frac{1}{n} y p', \tag{A.8}$$

$$T_{\bar{m}}^* = d' + \alpha d' + \frac{1}{m} Y p'. \tag{A.9}$$

Comparing the equilibrium tax rates, $\hat{t}_{\bar{m}}$ and $\hat{T}_{\bar{m}}$, with their efficient counterparts, $t_{\bar{m}}^*$ and $T_{\bar{m}}^*$, we arrive at the following conclusion: For $\alpha, \beta \neq 0$, the equilibrium tax rates can never coincide with the efficient tax rates. This can be easily seen by taking into account that $Y > X$ and $y > x$ cannot hold simultaneously, for $y + Y = z = x + X$. Only for $\alpha = \beta = 0$, may $\hat{t}_{\bar{m}}$ coincide with $t_{\bar{m}}^*$ and $\hat{T}_{\bar{m}}$ with $T_{\bar{m}}^*$; this occurs when each country is neither a net-importer nor a net-exporter, i. e., when $x = y$ and $X = Y$.[17]

# Appendix B: The impact of the curvature of the demand curve

In this appendix we provide the formulae which show the dependence of the comparative statics results, equations (12) to (17), on the curvature of the (inverse) demand curve. To see how $p''$ affects the marginal impact of $T$ on the equilibrium of the output market, suppose that, for a given equilibrium, $p''$ varies without affecting the values of $p'$ and the other variables. Then, differentiating equations (12)–(17) with respect to $p''$ yields

$$\frac{\partial}{\partial p''} \frac{\partial Q}{\partial T} = -\frac{Q(2p' - C'')}{p' \Lambda^2} < 0, \tag{B.1}$$

$$\frac{\partial}{\partial p''} \frac{\partial m}{\partial T} = \frac{(2p' - C'')\left[[Q(m-1) + n(2q-Q)]p' - (m-1)Qc'' - nqC'''\right]}{p'Q(p' - c'')\Lambda^2}. \tag{B.2}$$

A sufficient condition for $\frac{\partial}{\partial p''} \frac{\partial m}{\partial T} > 0$ is

$$\frac{y}{Y} = \frac{qn}{Qm} > \frac{1}{2} \frac{n+1-m}{m},$$

(for which in turn $Q < 2q$ is sufficient). That is, provided that the foreign firms' market share (scale) is not too large compared with that of the domestic firms,

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[17]BRANDER AND SPENCER (1985) show that, abstracting from environmental aspects, $\hat{t}_{\bar{m}}$ and $\hat{T}_{\bar{m}}$ are too low compared with their second-best counterparts.

the number of foreign firms falls more slowly the more convex/less concave the inverse demand curve is. Moreover, equation (B.1) shows that a more convex demand curve aggravates firms' output reduction while a less concave demand curve reduces firms' output increase. Similarly we find:

$$\frac{\partial}{\partial p''}\frac{\partial Y}{\partial T} = \frac{(2p' - C'')\Big[[2nq - (n+1)Q]p' + Qc'' - nqC''\Big]}{p'(p'-c'')\Lambda^2}, \qquad (B.3)$$

which is positive under the rather mild (sufficient) condition that $Q < \min\{2nq/(n+1), nqC''/c''\}$. Though equation (B.1) indicates that a higher value of $p''$ aggravates a firm's output reduction (reduces a firm's output increase), this effect is dominated by the slow down of market exit resulting in smaller reduction of $Y$ as $p''$ increases. Lastly, one obtains

$$\frac{\partial}{\partial p''}\frac{\partial y}{\partial T} = -\frac{n(2p'-C'')[(2q-Q)p'-qC'']}{p'(p'-c'')\Lambda^2}, \qquad (B.4)$$

which is negative for $Q < 2q$, and

$$\frac{\partial}{\partial p''}\frac{\partial z}{\partial T} = -\frac{Q(2p'+C'')}{p'\Lambda^2} < 0, \qquad (B.5)$$

the interpretation of which is straightforward.

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