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A MODEL OF TRADE AGREEMENTS AND CROSS-BORDER EXTERNALITIES

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This thesis examines a second-best trade agreement between the governments of two countries that tries to remedy the distortions arising from non-coordinated environmental policy. In a reciprocal-markets model with bidirectional cross-border pollution, it is found that if the cross-border pollution is sufficiently strong, a second-best trade agreement requires that both governments impose import tariffs on the goods whose production gives rise to pollution. Also, it is found that if governments cooperate both in trade and environmental policies, they will engage in free trade.

Keywords: cross-border pollution, production externality, trade agreement, environmental tax, imperfect competition, tax competition

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1. INTRODUCTION

The environment is a hot topic. The latest upswing in debate activity seems to be mainly concerned with the influence of carbon dioxide emissions on the looming environmental crisis that is global warming. In 2006, Al Gore's documentarised slideshow *An Inconvenient Truth* hit the theatres and spurred new highs in public environmental awareness. Later the same year, the Stern Review was released and, although subject to harsh criticism,[1] it provided the world with a lucid example of the potential economic consequences of global climate change. In 2007, the Intergovernmental Panel of Climate Change published its fourth Assessment Report which warned that changes in the global climate during the 21st century very likely would be greater than those observed during the 20th century unless emissions of greenhouse gases are reduced (IPCC 2007: 6).

While these reports have revolved in the public debate, much more of course has been written in the academic literature. One subject, which has instigated much scholarly thought, is the linkages between the environment and trade.[2] Especially, environmentalist concerns have been raised in the face of the increased trade liberalisation through intergovernmental agreements, such as GATT and NAFTA. It has been argued that trade liberalisation might lead governments to adopt environmentally inefficient environmental policies as a secondary means of protection for domestic firms from foreign competition.[3] Generally, the rationale behind such concerns is that environmental policy contains policy instruments similar to those of trade policy and that governments, thus, could have incentives to utilise it as an imperfect substitute when trade policy is more and more constrained.[4]

To address suggestions made by e.g. Abrego *et al.* (2001) and Ederington (2001) that domestic environmental policy for the above reason should be explicitly linked to trade negotiations, it becomes necessary to examine what such linkage should look like. In this thesis

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[1] See e.g. Nordhaus (2007a, 2007b) who criticises the Stern Review for, amongst other things, choosing a deceptively low discount rate.

[2] See e.g. Dean (1992) and Jayadevappa and Chhatre (2000) for general surveys of the literature. In addition, Jaffe *et al.* (1995) specifically discuss the impact of environmental regulation on firms' competitiveness.

[3] See e.g. Copeland (1990, 2000), Barrett (1994), Kennedy (1994), and Conrad (1996). Also, Ederington and Minier (2003) find empirical support for this argument.

[4] Another branch of the academic literature has focused on the location decision of firms and has been able to show that if governments compete using environmental policies, they may try to attract firms by undercutting each other's environmental norms to socially suboptimal levels. See e.g. Markusen *et al.* (1995), Hoel (1997), Tanguay and Marceau (2001), and Cole *et al.* (2006).

we will thus try to discern the properties of a second-best trade agreement for cooperating governments, anticipating that they later on will have incentives to set opportunistic environmental policies in the face of a negative cross-border externality (e.g. pollution) arising from production and imperfect competition.[5]

In order to tackle the above problem, we will build a partial-equilibrium model where governments in two countries involved in trade decide what levels to set for trade and environmental policy instruments (import tariffs and environmental taxes). Two firms (one in each country) will compete in supplying markets in both countries with a differentiated good, the production of which generates a negative externality that brings harm to both countries. In order to describe a situation where trade policy in the short run is constrained from being negotiated multilaterally while environmental policy is decided upon domestically and, thus, can be more easily changed, we will build an extensive-form game where trade policy is decided upon before environmental policy.

The remainder of this thesis will be organised as follows. In section 2 we will elaborate on how environmental can come to serve as a secondary trade barrier and relate our model to the literature. In section 3 we will provide a more exhaustive account of the model's general framework. In section 4 we will briefly analyse the incentives faced by the firms. In section 5 we will discuss the determination of cooperative and non-cooperative environmental taxes. In section 6 we will look at two different degrees of cooperation and then discern the properties of the second-best trade agreement. And finally, in section 7 we will conclude.

2. LITERARY SURVEY

The literature on strategic environmental policy, to which we endeavour to contribute, originates from that of strategic trade policy, where it has been noted that trade regulation contains elements of a prisoner's dilemma. That is, although global welfare would generally be maximised through the imposition of free trade, governments tend to perceive it as their dominant strategy to offer some level of protection to shelter domestic firms from international competition. As governments share this perception, there is—to the disutility of all—excessive protection in the resulting equilibrium.[6]

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[5] See Hoel (1999) for a general discussion on cross-border externalities.

[6] See e.g. Brander and Spencer (1985) and Copeland (1990).

Countries have responded by trying to coordinate on restricting trade policy through international agreements (e.g. GATT, NAFTA, and EU). Copeland (1990: 86), however, explains that trade agreements, due to the political limits to cooperation, tend to be incomplete contracts. Also, given the abundance of instruments that can be used to influence the flow of trade, there will nevertheless remain loopholes in trade agreements that governments might take advantage of to give preferential treatment to domestic firms.[7]

For environmentalists, this is good news. Governments bound by a trade agreement would have little or no incentive to distort environmental policy as a means of sheltering domestic firms from foreign competition and cheat on the trade agreement, if there were more effective policy instruments, whose use the trade negotiators had neglected or not yet been able to restrict (Copeland 2000: 422). However,

> trade negotiators are well aware of the loophole problem in trade agreements and much of the recent trade policy agenda has been aimed at closing such loopholes by expanding the scope of trade agreements to constrain subsidies and other instruments. This suggests that the more comprehensive is the trade agreement, the fewer are the loopholes, and the more likely it is that governments may be tempted to use environmental policy as a trade policy.
>
> (Copeland 2000: 422)

If we accept these conclusions, increasing trade liberalisation calls for analysis of how governments make such substitution and how they best should account for this behaviour. It is issues such as these that the literature on strategic environmental policy analyses and tries to solve.

A typical starting point in doing so has been that market solutions are socially suboptimal for goods with negative externalities (e.g. pollution) as each of the producers of the goods only take private costs into consideration when deciding upon their level of production, which on an aggregate scale impose significant social costs.[8] Thus, in order to reach the socially optimal production, calls are made for some form of intervention.

In terms of environmental efficiency, an optimal tax on a polluting good would shift production from the market equilibrium to the social optimum. The rate of such a tax should

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[7] One implication of Copeland (1990: 103-6) is that, depending on the properties of the government objective function, a trade agreement, that restricts the use of the most efficient policy instruments, might actually make consumers worse off by making other instruments, whose use imposes larger costs on consumers, attractive.

[8] The same reasoning can naturally be applied also to consumers' choices in cases where the externality arises from the consumption of a good.

equal the marginal damage of the externality (what has been called the *pigouvian* tax rate). In general, the insights in the strategic environmental policy literature originate from a quite reasonable assumption that governments make trade-offs between environmental efficiency and other objectives when setting environmental policies. And so, they have incentives to set environmental policies other than those optimal from an environmental perspective.

While the idea that governments will pursue trade goals through environmental policy seems to be supported by anecdotal evidence (e.g. Lai and Hu 2008: 209-10; Conrad 1996: 65), literary surveys tend to find little support for such claims (Dean 1992; Jaffe *et al.* 1995). Multiple reasons for this have been suggested. Amongst others Jaffe *et al.* (1995: 158) mentions that compliance costs of environmental regulation might be too small to have a significant impact on firms' competitiveness and that it thus would not be in a government's interest to alter environmental policy because of trade considerations. However, Ederington and Minier (2003: 139) argue that older empirical studies have 'implicitly [been] assuming away the possibility that trade considerations may play a role in the setting of environmental policy' by treating the level of environmental regulation as exogenously determined. When modelling environmental regulation endogenously, they find 'a much stronger impact' of environmental policy on net import levels than previous studies (Ederington and Minier 2003: 149). Also, Copeland (2000: 422) in a theoretical setting argues that the case for linking negotiations on trade and environmental policy may become stronger as international trade agreements become more comprehensive and the incentives to let environmental policy act in trade policy's place grow stronger.

When addressing environmental policy implementation in the intersection of pollution and trade, many scholars have found a starting-point in the trade model of Brander and Spencer (1985).[9] The alterations, which are most closely related to the model we present here, are probably those of Lai and Hu (2008), Kennedy (1994), and Tanguay (2001). These models are so-called reciprocal-markets models,[10] which describe firms that supply their products to domestic as

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[9] Brander and Spencer (1985) show that a government can maximise the profits of a domestic firm by subsidising its exports, whereby the firm increases its output from that of a Cournot duopolist to that of a Stackelberg leader. Apart from the models discussed in the text, examples of models developed from Brander and Spencer (1985) are Duval and Hamilton (2002), Rauscher (1994), Conrad (1996), and Barrett (1994).

[10] Brander and Spencer (1985) assume that consumption of the produced goods is in an external market. Barrett (1994) and Walz and Wellisch (1997) are two examples of models that discuss trade and pollution while keeping the assumption of an external market. However, '[b]y making the assumption that all consumption is elsewhere, one neglects an additional way in which environmentally disguised interventionist trade or industrial policy might yield welfare gains beyond reduction in environmental damage' (Conrad 1996: 66).

well as foreign markets as opposed to models where firms supply their products to either home or foreign markets.

Kennedy (1994) follows the implied welfare-increasing recommendation of Brander and Spencer (1985) and assumes free trade. Under this assumption, he builds a model where governments, who here are restricted to using only an environmental tax, can have an incentive to set its level environmentally inefficient so as to subsidise domestic firms. In contrast, the model we analyse here does not assume free trade, but lets the degree of free trade be chosen endogenously by governments in keeping with the objective of formulating a second-best trade agreement.

Tanguay (2001) differs from Kennedy (1994) in that he does not assume free trade, but, like us, models it endogenously. Tanguay (2001), however, lets governments set trade and environmental policy instruments simultaneously, while we choose to let these decisions be made sequentially. The setup we have chosen where trade policy is decided upon and committed to before environmental policy is set is meant to describe the situation where governments need to commit themselves 'in the framework of certain international trade agreements, such as the World Trade Organization negotiations, whereas environmental policies can be changed more easily' (Lai and Hu 2008: fn. 8).[11] Our setup, thus, seems an adequate one.

By attempting to establish the properties of a second-best trade agreement, we share a common objective with Lai and Hu (2008), who also use the sequential setup where governments set trade policy before setting environmental policy. However, Lai and Hu (2008) focus on consumption externalities whereas our focus is on production externalities. In that setting they find that 'second-best tariff agreement requires that importing countries subsidize the imported goods whose consumption gives rise to pollution, if the [cross-border] pollution is sufficiently strong' (Lai and Hu 2008: 226). As will be seen, these findings are reversed when the source of pollution is altered.

There are a number of studies that address the issue of cross-border, production-type pollution through second-best trade measures. Markusen (1975), Baumol and Oates (1988), Ludema and Wooton (1994), and Copeland (1996) all show that it may be in the interest of an importing country to levy a tariff on the imported good in order to reduce cross-border pollution. However, there are several significant differences, the primary one being that they deal with unilaterally optimal tariffs, whereas we focus on cooperatively optimal tariffs.

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[11] See the second half of Copeland (2000) for a discussion on the feasibility of different time structures.

3. GENERAL FRAMEWORK

Suppose there are two countries, henceforth labelled Home and Foreign, with each having one firm producing a differentiated good. Each firm sells in both Home and Foreign markets. Apart from their differences in production, Home and Foreign are identical in every respect.[12] Where possible, we focus on the description of Home in order to avoid repetition.

Following Lai and Hu (2008), we assume that firms do not incur any transportation costs in supplying either market, but that such costs prevent third-party arbitrage. Again following Lai and Hu (2008), we assume that markets are segmented. That is, each firm perceives the markets as distinct and sets output for the market independently.

Home and Foreign variables are separated through the use of subscripts (*H* for Home, *F* for Foreign). In the case of output variables, a more specific notation is called for. Thus, we let q_{HH} denote the output of the Home firm for the Home market and q_{HF} its output for the Foreign market. Similarly, we let q_{FH} denote the output of the Foreign firm for the Home market and q_{FF} its output for the Foreign market.

Whereas aggregate pollution impose significant social costs on both countries (which is made explicit in the governmental utility functions presented in section 5), consumers are assumed to perceive the private costs of pollution from one extra unit of consumption as negligible. The demand for the products produced by the two firms is embodied in the following market demand functions:

$$p_{HH} = \beta - q_{HH} - \gamma q_{FH}, \tag{1}$$

$$p_{FH} = \beta - q_{FH} - \gamma q_{HH}, \tag{2}$$

$$p_{FF} = \beta - q_{FF} - \gamma q_{HF}, \tag{3}$$

and

$$p_{HH} = \beta - q_{HF} - \gamma q_{FF}, \tag{4}$$

where p_{HH} is the price of the Home product in the Home market, p_{FH} that of the Foreign product in the Home market, p_{FF} that of the Foreign product in the Foreign market, p_{HF} that of the Home

[12] For analyses that depart from this assumption, see e.g. Copeland (2000), Copeland and Taylor (1994), and Duval and Hamilton (2002).

product in the Foreign market, $\beta \in (0,\infty)$ is a demand parameter (or the 'choke price' at which demanded output is reduced to zero), and $\gamma \in (0,1)$ is an exogenous inverse measure of the degree of product differentiation.[13] To simplify, we limit our analysis to $\gamma = ¼$.[14]

In what follows, we construct a three-stage game. In the third stage, the two firms engage in Cournot competition whereby they simultaneously set their output levels (q_{HH}, q_{HF}, q_{FH}, and q_{FF}) to maximise profits, given import tariffs and environmental taxes. Governments anticipate the firms' responsiveness to import tariffs and environmental taxes and in the second stage, thus, set environmental taxes so as to maximise their utility given the import tariffs and the future responsiveness of the firms. Similarly, given the future responsiveness of all players, governments, in the first stage, set import tariffs to maximise their utility.

In order to enable a more thorough analysis of the game, we consider a few different setups. In the second stage, we start off by discussing a non-cooperative scenario, wherein governments set environmental taxes to maximise its own utility and ignores whatever ramifications its decision might have on the other country. We move on to discuss a cooperative scenario, wherein governments set environmental taxes to maximise joint rather than individual utility.[15]

In the first stage, we discuss two cases, according to the presence or absence of cooperation in environmental taxes. The first case is that of full cooperation, in which the governments cooperate in both their trade and environmental policies by maximising joint utility. The other is the case of partial cooperation, in which the two governments cooperate in regard to trade but not environmental policy.

In order to obtain sub-game perfect Nash equilibria, we employ backward induction. Consequently, the first stop in our analysis is the third (and more importantly *final*) stage. The firms make their output decisions, when environmental and trade policies are already set and not

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[13] Accordingly, $\gamma = 1$ would correspond to the case where products are perfectly homogeneous, while $\gamma = 0$ would correspond to the case where products are perfectly heterogeneous, that is *not* substitutes.

[14] See section 7 for a discussion on the significance of this assumption.

[15] A descriptive approach would not be as restrictive, but would affirm the fact that full cooperation is not likely to be politically feasible and that governments do not cooperate as much as negotiate. Thus, such an attempt could construct trade negotiations as, e.g. a Nash bargaining game, which could very well have asymmetric equilibria depending on which threat points governments could commit to. However, as the objective of this thesis is prescriptive rather than descriptive, our approach seems to be an adequate one. See Copeland (1990) for a discussion on such trade negotiations and an example of how to model them.

susceptible to any firm influence.[16] Thus, the firms' problem is to maximise profits *given* import tariffs and environmental taxes.

4. OUTPUT DECISIONS

So as to simplify, marginal production costs are assumed to be constant and are normalised to zero. Thus, the profits of the two firms are

$$\pi_H = (p_{HH} - t_H) \cdot q_{HH} + (p_{HF} - t_H - \tau_F) \cdot q_{HF} \tag{5}$$

and

$$\pi_F = (p_{FF} - t_F) \cdot q_{FF} + (p_{FH} - t_F - \tau_H) \cdot q_{FH}, \tag{6}$$

where t_H is the environmental tax imposed on Home output by the Home government and τ_F is the import tariff imposed on Home exports by the Foreign government. Likewise, t_F is the environmental tax imposed on Foreign output by the Foreign government and τ_F is the import tariff imposed on Foreign export by the Home government. In each profit function, the first term is the profit made from that firm's domestic market and the second term is the profit from the firm's foreign market.

By substituting equations (1)-(4) in equations (5) and (6) and maximising profits with respect to outputs, we obtain the first-order conditions:

$$\frac{\partial \pi_H}{\partial q_{HH}} = \beta - 2q_{HH} - \frac{1}{4} q_{FH} - t_H = 0, \tag{7}$$

$$\frac{\partial \pi_H}{\partial q_{HF}} = \beta - 2q_{HF} - \frac{1}{4} q_{FF} - t_H - \tau_F = 0, \tag{8}$$

$$\frac{\partial \pi_F}{\partial q_{FF}} = \beta - 2q_{FF} - \frac{1}{4} q_{HF} - t_F = 0, \tag{9}$$

and

[16] For models which allow firms to engage in rent-seeking activities such as lobbying in order to win the favour of governments, see e.g. Mitra (1999).

$$\frac{\partial \pi_H}{\partial q_{HF}} = \beta - 2q_{FH} - \frac{1}{4}q_{HH} - t_F - \tau_H = 0\,. \tag{10}$$

Solving these equations for outputs yields the equilibrium outputs:

$$q_{HH}^e = \frac{4}{63}\left(7\beta - 8t_H + t_F + \tau_H\right), \tag{11}$$

$$q_{HF}^e = \frac{4}{63}\left(7\beta - 8t_H + t_F - 8\tau_F\right), \tag{12}$$

$$q_{FF}^e = \frac{4}{63}\left(7\beta - 8t_F + t_H + \tau_F\right), \tag{13}$$

and

$$q_{FH}^e = \frac{4}{63}\left(7\beta - 8t_F + t_H - 8\tau_H\right), \tag{14}$$

where superscript e denotes equilibrium.

From these reaction functions we can make out how changes in the import tariffs and environmental taxes affect what level of output the firms choose in equilibrium. An increase in the Home environmental tax ($t_H\uparrow$) causes a decrease in Home output ($q_{HH}\downarrow$ and $q_{HF}\downarrow$) and an increase in Foreign output ($q_{FF}\uparrow$ and $q_{FH}\uparrow$) as the Home firm sees its cost advantage decrease in relation to its competitor.

An increase in the Home import tariff ($\tau_H\uparrow$) has no effect on production for the Foreign market but causes the Home output for the Home market to increase ($q_{HH}\uparrow$) and the Foreign output for the Home market to decrease ($q_{FH}\downarrow$). In total, Home output increase and Foreign output decrease. Similar effects apply to changes in the Foreign environmental tax (t_F) and Foreign import tariff (τ_F).

Having arrived at the equilibrium outputs in the third and final stage, we now consider the decisions faced by governments in the second stage.

5. ENVIRONMENTAL TAXES

The production of the goods generates pollution in the country where the production takes place. This pollution does, however, not confine itself to that country, but there is also a cross-border

effect on the other country. This cross-border pollution is assumed to be bidirectional and symmetric.

Leaving potential philosophical conundrums aside, we follow a common convention in the literature by assuming the governments' utility functions to be the sum of consumer surplus, profits, and government revenue less damage from pollution.[17, 18] The Home government utility is, thus, given by

$$w_H = \frac{\left(q^e_{HH}\right)^2 + \left(q^e_{FH}\right)^2}{2} + \pi_H + t_H \cdot \left(q^e_{HH} + q^e_{HF}\right) + \tau_H \cdot q^e_{FH} - \theta \cdot \left(q^e_{HH} + q^e_{HF}\right) - \delta \cdot \theta \cdot \left(q^e_{FF} + q^e_{FH}\right), \tag{15}$$

where the first term is Home consumer surplus,[19] $\theta \in [0, \infty)$ the environmental damage stemming from the production of one unit of output, and $\delta \in [0,1]$ a measure of the strength of the cross-border pollution.[20] We assume that the environmental damage (θ) is less than the demand parameter (β) in order to rule out the situation where the marginal damage of producing one unit is greater than the marginal utility of consuming one unit.

Similarly, the Foreign government utility is given by

$$w_F = \frac{\left(q^e_{FF}\right)^2 + \left(q^e_{HF}\right)^2}{2} + \pi_F + t_F \cdot \left(q^e_{FF} + q^e_{FH}\right) + \tau_F \cdot q^e_{HF} - \theta \cdot \left(q^e_{FF} + q^e_{FH}\right) - \delta \cdot \theta \cdot \left(q^e_{HH} + q^e_{HF}\right). \tag{16}$$

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[17] Government revenue from taxes and tariffs could, as in Lai and Hu (2008: 213), be distributed to consumers in the form of lump sums or, alternatively, be used to remedy the damage caused by pollution.

[18] The government utility function should not necessarily be interpreted as representing social welfare. It is only the payoffs to the government that affects what happens in equilibrium.

[19] It can easily be shown that consumer surplus takes this form. Remember that q^e_{HH} is the Cournot equilibrium output for the q_{HH} market and let p^e_{HH} be the corresponding Cournot equilibrium price. Consumer surplus will then be $\int_0^{q^e_{HH}} \left(a - q_{HH} - \gamma q_{FH} - p^e_{HH}\right) dq_{HH} = \int_0^{q^e_{HH}} \left(a - q_{HH} - \gamma q_{FH} - \left[a - q^e_{HH} - \gamma q_{FH}\right]\right) dq_{HH} = \int_0^{q^e_{HH}} \left(-q_{HH} + q^e_{HH}\right) dq_{HH} = \left(q^e_{HH}\right)^2 / 2$.

[20] Accordingly, $\delta = 1$ corresponds to the case where pollution affects both countries to an equal extent regardless of where production takes place, while $\delta = 0$ corresponds to the case where pollution confines itself entirely to its country of origin.

5.1. Non-cooperative scenario

The two governments maximise their respective utility with respect to environmental taxes (t_H and t_F), which yields the following first-order conditions:

$$\frac{\partial w_H}{\partial t_H} = \frac{8}{63}\left(-\frac{5}{3}\beta - \frac{122}{21}t_H - \frac{11}{21}t_F - \frac{1}{63}\tau_H + \frac{4}{63}\tau_F + 8\theta - \delta\theta\right) = 0 \tag{17}$$

and

$$\frac{\partial w_F}{\partial t_F} = \frac{8}{63}\left(-\frac{5}{3}\beta - \frac{122}{21}t_F - \frac{11}{21}t_H - \frac{1}{63}\tau_F + \frac{4}{63}\tau_H + 8\theta - \delta\theta\right) = 0\,. \tag{18}$$

Solving for the environmental taxes, we obtain the non-cooperative environmental taxes:

$$t_H^n = \frac{1}{19}\left(-5\beta - \frac{166}{2331}\tau_H + \frac{449}{2331}\tau_F + 24\theta - 3\delta\theta\right) \tag{19}$$

and

$$t_F^n = \frac{1}{19}\left(-5\beta - \frac{166}{2331}\tau_F + \frac{449}{2331}\tau_H + 24\theta - 3\delta\theta\right), \tag{20}$$

where superscript n denotes non-cooperation.

To reach a better understanding of this result we note that there are several mechanisms at work affecting the non-cooperative environmental taxes. The markets being taxed are subject to two different market imperfections: negative production externalities and imperfect competition. The externalities, were they the only market imperfection affecting the markets, would result in an environmental tax at the pigouvian level equalling marginal damage (θ). However, the imperfect competition results in a welfare loss when the producers use their market power to extract some of the consumer surplus by setting their outputs at a level where price no longer equal marginal cost. To remedy this welfare loss the governments would prefer not to tax but to subsidise production and shift supply towards the perfect competition equilibrium. Thus, these two market imperfections sway the governments' policies in opposite directions and the resulting tax rate would generally be lower than what is called for by the externalities and higher than what is called for by the imperfect competition.

We also need to consider the mechanisms stemming from the fact that we model an open economy. First, as production is polluting and as governments, *ceteris paribus*, would prefer for production to take place in the other country, they have incentives to set higher environmental taxes than what would be expected in closed economies in order to shift pollution away from home. As pollution brings harm even if it stems from the foreign country, these incentives are reduced as the strength of the cross-border pollution increases. If the pollution is perfectly cross-border ($\delta = 1$) and affects both countries equally these incentives disappear.

Second, an increased domestic import tariff decreases the output for domestic consumption which yet worsens the welfare loss from imperfect competition. An increased domestic import tariff amplifies the governments' incentives to subsidise rather than tax with the result of a negative relationship between the domestic import tariff and the domestic environmental tax.

Third, while an increased domestic import tariff decreases total domestic consumption it increases domestic production. This effect strengthens the governments' incentives to shift pollution and amplifies the negative relationship between the domestic import tariff and the domestic environmental tax.

Fourth, there are two separate ways for foreign import tariffs to affect the domestic environmental taxes. On the one hand, we have a direct effect when a decreased foreign import tariff prompts an increase in domestic output (as noted in section 4). To deal with the result of increased pollution the domestic government would want to increase its environmental taxes. On the other hand, we have an indirect effect when a decreased foreign import tariff causes the foreign environmental tax to increase, which in turn gives the domestic government an incentive to free ride by lowering its own environmental tax. From the positive relationship between environmental taxes and foreign import tariffs in equations (19) and (20) we see that in our model the direct effect is outweighed by the indirect effect. We have the following proposition:

Proposition 1. *In the non-cooperative scenario, each government's environmental tax increases as its own import tariff decreases and as the other governments import tariff increases.*

5.2. Cooperative scenario

In this subsection we examine the scenario where the two governments coordinate their decisions regarding environmental taxes (t_H and t_F). The cooperative problem consists of choosing environmental taxes so as to maximise the sum of the two utility functions given by equations (15) and (16). That is,

$$\max_{\{t_H, t_F\}} W = w_H + w_F . \tag{21}$$

Solving the first-order conditions for the environmental taxes we arrive at the cooperative environmental taxes:

$$t_H^c = \frac{1}{2}\left(-\beta - \tau_F + 3\theta + 3\delta\theta\right) \tag{22}$$

and

$$t_F^c = \frac{1}{2}\left(-\beta - \tau_H + 3\theta + 3\delta\theta\right), \tag{23}$$

where superscript *c* denotes cooperation.

We see that the cooperative environmental taxes increase with the strength of the cross-border pollution which reflects that governments in this scenario account for pollution also in the other country. Looking back at equations (19) and (20) we see that this contrasts with the non-cooperative scenario where stronger cross-border pollution weakened governments' incentives to tax production since they would not be as able to decrease the pollution affecting them.

Another result that contrasts with those from the non-cooperative scenario is that governments no longer have incentives to adjust environmental taxes in relation to domestic import tariffs. In the non-cooperative scenario such adjustments were appealing in that they shifted costs away from home. But when governments in the cooperative scenario also consider the costs inflicted on one another the adjustments lose their appeal.

When the negative relationship between domestic import tariffs and domestic environmental taxes disappears also the indirect effect of changes in the foreign import tariff disappears. When cooperating, governments no longer have any incentives to free ride by shifting pollution away from home by inflating the rate of environmental taxes. This leaves us with only the direct effect of changes in foreign import tariffs resulting in a negative relationship between the environmental tax and the foreign import tariff.

That being said, it might be of interest to compare the size of the environmental taxes in the two scenarios. By subtracting the Home non-cooperative environmental tax from the Home cooperative environmental tax we obtain the following expression:

$$t_H^c - t_H^n = -\frac{9}{38}\beta + \frac{166}{44289}\tau_H - \frac{45287}{88578}\tau_F + \frac{9}{38}\theta + \frac{63}{38}\delta\theta . \tag{24}$$

The sign of equation (24) is ambiguous. That is, non-cooperative environmental taxes may be above or below the cooperative taxes. We see that the size of equation (24) decreases as the strength of the cross-border pollution decreases and as the demand parameter increases. Thus, the weaker the cross-border pollution and the higher the demand parameter, the more likely is it that the non-cooperative environmental taxes will be greater than the cooperative environmental taxes. Also, in the special case where pollution is purely local ($\delta = 0$) and the two countries engage in free trade ($\tau_H = \tau_F = 0$) the cooperative environmental taxes will be strictly lower than the non-cooperative environmental taxes. This gives us the following proposition:

Proposition 2. *In the presence of cross-border pollution, the non-cooperative environmental taxes may be above or below the cooperative taxes. When the cross-border pollution is weaker, or the demand parameter is higher, the more likely it is that the non-cooperative environmental taxes will be greater than the cooperative environmental taxes.*

Although the cooperative outcome is Pareto superior to the non-cooperative equilibrium, either government could be made better off by choosing the non-cooperative environmental tax, given that the other government still chooses the cooperative environmental tax. Through this potential increase in utility, both governments have incentives to deviate from the outlined environmental agreement. With this understanding we move on to the next section where we will analyse the decisions faced governments in the first stage.

6. IMPORT TARIFFS

If there are no means for the two governments to credibly commit to coordinating their environmental policies, then a trade agreement accounting for this fact could serve as a second-best method to address the problem of cross-border pollution.

In order to address the question of what properties a second-best trade agreement accounting for the distortion arising from non-coordinated environmental policies should have, we consider two cases: the case where the governments cooperate in both trade and environmental policy (full cooperation) and the case where they cooperative solely in trade policy (partial cooperation).

6.1. Full cooperation

In order to arrive at the import tariffs in the full cooperation case, we substitute the cooperative environmental taxes from equations (22) and (23) into the combined government utility function, that is the sum of equations (15) and (16), and maximise with respect to import tariffs. That is,

$$\max_{\{\tau_H,\tau_F\}} W = w_H + w_F . \tag{25}$$

Thus, we arrive at the following first-order conditions:

$$\frac{\partial W}{\partial \tau_H} = -\frac{152}{1323}\tau_H + \frac{44}{1323}\tau_F = 0 \tag{26}$$

and

$$\frac{\partial W}{\partial \tau_F} = -\frac{152}{1323}\tau_F + \frac{44}{1323}\tau_H = 0 . \tag{27}$$

Solving for the import tariffs we obtain the full-cooperation import tariffs:

$$\tau_H^f = \tau_F^f = 0 , \tag{28}$$

where superscript *f* denotes full cooperation.

We here see that once the distortion arising from the cross-border pollution is dealt with through an environmental agreement there is no need to tackle it further through any alterations to the standard trade agreement. Thus, we have the following proposition:

Proposition 3. *If the two governments cooperate in both import tariffs and environmental taxes, they will engage in free trade.*

This should not come as a very surprising finding. As Anderson and Blackhurst (1992: 20) comment 'trade *per se* is not a direct cause of environmental problems' and if appropriate environmental policies are in place there should not in general be any need to restrict it. As should be expected, this result is also reached by Lai and Hu (2008) in the case of consumption externalities.

6.2. Partial cooperation

We now move to the case of partial cooperation, where we formulate the second-best trade agreement. When governments coordinate solely on trade policy, they need to consider the distortion arising from the non-coordinated environmental policies.

In order to do this we substitute the non-cooperative environmental taxes from equations (19) and (20) into the combined government utility function and maximise with respect to import tariffs. Solving the first-order conditions for the tariffs we obtain the second-best import tariffs:

$$\tau_H^{sb} = \tau_F^{sb} = \frac{45}{148}\left(-\beta + \theta + 7\delta\theta\right), \tag{29}$$

where superscript *sb* denotes second-best.

From equation (29) we see that free trade no longer should be expected to be the optimal policy in the case of partial cooperation. The second-best import tariffs can be either greater than or lower than the first-best import tariffs that in section 6.1 were found to be equal to zero. The relationship between the first-best and second-best cooperative import tariffs depends on the strength of the cross-border pollution (δ) relative to the demand parameter (β). Thus, we have the following proposition:

Proposition 4. *If governments cooperate in trade policies, but not in environmental taxes, then the resultant second-best cooperative import tariffs may be either greater than or lower than the first-best cooperative import tariffs, which are equal to zero. The stronger the cross-border pollution, the more likely it is that the second-best import tariffs will be greater than zero. On the other hand, the larger the demand parameter, the more likely it is that the second-best import tariffs will be less than zero.*

We first consider the case where pollution is strictly local (i.e. $\delta = 0$). In this case, the second-best import tariffs are negative (i.e. subsidies).[21] Were the governments to engage in free trade, they would have incentives to substitute import subsidies with higher environmental taxes so as to shift production (and pollution) away from home. Therefore, governments agree to subsidise imports to weaken these incentives.

This should be contrasted with the case where cross-border pollution is strong. If it is sufficiently strong then the second-best import tariffs will be greater than the first-best import tariffs, which equal zero. Were the governments to engage in free trade in this case, they would

[21] Remember from section 5 that $\beta > \theta$.

have incentives to substitute the protection from import tariffs with lower environmental taxes so as to subsidise domestic production and capture foreign rents. Therefore, governments agree to impose import tariffs to weaken these incentives.

7. CONCLUDING REMARKS

In this thesis we have shown that the second-best trade agreement striving to address the combined nuisance of negative cross-border externalities and imperfect competition will require governments to levy import tariffs on the goods whose production gives rise to pollution, if the cross-border externality is sufficiently strong. The reason for this is that when the cross-border externality is sufficiently strong, the non-cooperative environmental taxes levied on production will be lower than the cooperative environmental taxes. On the other hand, if the cross-border externality is relatively weak, the second-best trade agreement will require governments to subsidise the imported goods.

Here it might be appropriate to emphasise some caveats. In section 3 we limited our analysis to one specific level of product differentiation. Informal analysis of the general case suggests that our analysis is applicable also when $\gamma \in (0,½)$. However, for other levels of product differentiation the properties of the second-best trade agreement change. Roughly when $\gamma \in (½,¾]$ the agreement is strictly one of import tariffs and roughly when $\gamma \in (¾,1)$ it is strictly one of import subsidies. Intuitively, as products become more homogeneous (i.e. $\gamma\uparrow$) we should expect output to go up and thereby reduce the welfare loss from imperfect competition. This would allow for governments to fight pollution more aggressively by raising environmental taxes. Moreover, as output increases, pollution increases which also would cause governments to raise environmental taxes. There seems to be some government trade-off eluding us that could explain the findings of the informal analysis. Nevertheless, it is safe to say that whereas Lai and Hu (2008) in the case of consumption externalities are able to draw quite clear-cut conclusions, the case of production externalities appears to be somewhat more ambiguous.

Finally, the model we have discussed offers several potential extensions. One would be to expand firms' strategy sets to include also investments in abatement. In this thesis we have assumed that governments impose per unit environmental taxes but it seems more plausible that it would be some specific aspect of production which causes environmental damage and so environmental taxes should, if possible, be more closely connected to that aspect. And as environmental policies should be expected to be publicly announced before they are imposed firms stand the choice to alter production so as to limit the taxed aspects. The three-stage game

we have discussed would, thus, expand into a four-stage one with an abatement stage in between the present stage two and stage three. The strategic consideration for firms becomes to trade off the costs from abatement to taxation. But eagerly anticipating graduation, we leave extensions to future research.

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