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Strategic Environmental Policies in the Presence of Foreign Direct Investment*

By

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Abstract

We analyse strategic environmental standards in the presence of foreign direct investment (FDI). A foreign firm located in a host country competes with a domestic firm in another country to export a homogeneous good to a third country. We also extend the model to allow the number of FDI to be endogenous. When the number of foreign firms is exogenous, the FDI host country always applies stricter environmental regulation. However, under free entry and exit of foreign firms, the FDI host country may apply lower standards under both non-cooperative and cooperative equilibrium.

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1 Introduction

The volume of Foreign Direct Investment (FDI) has been increasing rapidly for the last two decades. According to UNCTAD, the ratio of inward plus outward FDI stocks to global GDP is 21 per cent, and the foreign affiliate exports now make up about one-third of total world exports. More and more countries are creating attractive conditions for FDI. During 1991-1997, 94 per cent of the regulations regarding FDI were relaxed to promote FDI in both developed and developing countries (see UNCTAD (1998)).

It has been argued that long-term pollution restrictions cause polluting activities to be relocated in countries with relatively lower pollution standards. Low and Yeates (1992) found that during the 1970s and 1980s many polluting industries migrated through FDI flows towards lower income countries with less strict environmental restrictions. The production of highly poisonous substances such as chemical pesticides and heavy metals like copper, zinc, and lead have also changed location (see Anderson et al (1995, p.66)). Lucas et al (1992) show that the stricter regulation of pollution-intensive production in the OECD countries has led to significant displacement of polluting activities. Xing and Kolstad (1998) found that the location of the US chemical industry was affected by the laxity of the host country's environmental standards. Thus, trade and investment liberalisation are seen to create pollution havens by developing channels through which polluting industries shift to less developed countries. This in turn may increase the possibility of a strategic environmental policy competition amongst countries who want to attract the relocated investment. In particular, there could be *a race towards the bottom*, where countries lower their standards in an inter-jurisdictional contest in order to attract capital and generate employment (Bhagwati, 1995).

Although the theoretical foundations of the interface between trade and environment stem back to 1970s, the international debate and negotiations began in the early 1990s during the Uruguay Round of trade-environment negotiations. The most potent concern arises from the fear that capital and jobs will move to countries with lower environmental standards. Because of these fears, countries with higher environmental standards have asked for the inclusion of environmental standards in the World Trade Organisation (WTO), requesting either that standards be raised in the low-standards countries or that high-standard countries should be allowed to countervail the implied subsidy.[1]

Given the extensive role being played by FDI in the globalisation process and the ever increasing concern for environment throughout the globe, it is surprising that there is only a limited literature on the interface between FDI and the environment. Markusen et al (1993) analyse the location decisions of two firms in a two region model where the government in one region is passive in the face of investment flows. In Markusen et al (1995), the second government is brought into play and they then analyse the outcome of the competition between the two countries to encourage the entry of a foreign firm (or to discourage the entry of a foreign firm, if the disutility from pollution is sufficiently high). Lahiri and Ono (2000) develop a one country model in which they analyse the different effects of tax and quantity restrictions on pollution control in the presence of an endogenous number of foreign firms.

Under the WTO rules, it is becoming more and more difficult to use trade policies for strategic purposes such as increasing market share of home-based firms. As a result, many countries are using environmental policies as strategic instruments in trade. For example, some believe that the environmental restriction in Denmark that beer should be sold in bottles rather than cans is in part a measure to protect domestic beer producers against German ones. It is therefore important to analyse the issue of strategic environmental policies, particularly in the presence of FDI. None of the above papers on the interface between environment and FDI consider strategic

[1] For example, a proposal has been introduced in the U.S. congress, so called green bill, which would authorise the administration to impose eco-dumping duties against lower environmental standards abroad. See Bhagwati (1995) for further discussion on this proposal. It is not clear, however, whether the actual motivation for the bill is the improvement of world environment, or it is simply a protectionist measure.

environmental policies. Barrett (1994) analyses environmental policies in a model where two countries compete to export to a third country. However, the firms in his model are local and fixed in number, and his main concern is to compare the results under Cournot competition with that under Bertrand competition. The purpose of this paper is to fill an important gap in the literature by considering strategic environmental policies in the presence of FDI. In particular, we analyse the role of free entry and exit of foreign firms on the strategic environmental policies.

In the benchmark version of our model there are two firms (one from each country) compete to export a homogeneous good to a third country. That is, both groups of firms are assumed to be export-oriented. The benchmark model extends the well-known Brander and Spencer (1985) model of strategic trade policy in several ways.[2] First, the firm located in country 1 is owned by foreigners. Second, we introduce pollution and environmental policies as opposed to trade policy in Brander and Spencer (1985). Pollution arises during production by both types of firms, and both firms possess a technology for abating pollution they generate. We rule out cross-border pollution. The policy available to the governments in the two countries is a quantity restriction on pollution. It is assumed that there is unemployment in both countries, and that the profits of FDI are repatriated to the source countries. Hence, country 1 benefits from FDI only through the employment generated by foreign firms, but can not exploit any rents from the profits of FDI. Country 2, on the other hand, benefits from the profit earned by the domestic firm as well as the employment created by export-oriented production. However, both the countries dislike pollution that accompanies production.

We then extend the benchmark model to allow the number of FDI to be endogenous as in Lahiri and Ono (1998a). The number of foreign firms is affected by the government in country 1 (the host to FDI) by the use of quantity restrictions on

[2] The Brander and Spencer (1985) model of strategic trade policy has had extensively applications in the literature. See, for example, Ishikawa and Spencer (1999) and Qiu (1995) for two recent applications.

pollution, as the FDI equilibrium is determined by equating the profits of the foreign firms to an exogenous level representing the reservation level of profits which the foreign firms could obtain if they invested in other countries.

Using the above specification, we examine the equilibrium levels of pollution restrictions when the governments determine their policies cooperatively and non-cooperatively. We also compare the outcome of these policies for the general model with that of the benchmark one, i.e., we examine the effect of free entry and exit of FDI on policies.

The benchmark model is detailed in the following section. In section 3, we derive the properties of the non-cooperative equilibrium, while section 4 compares the equilibrium in the presence and absence of free entry and exit. It also includes a comparison between non-cooperative and cooperative equilibria. Finally, some concluding remarks are made in section 5.

2 The Benchmark Model

In this model there are two exporting countries (labelled as country 1 and country 2) and one consuming (importing) country. There is one foreign firm which operates in country 1 and one domestic firm in country 2 for the oligopolistic market of a homogeneous good in the consuming country. In section 4 we should consider the case of free entry and exit of foreign firms. We assume the existence of unemployment in the two producing countries.[3] The inverse demand function for oligopolistic good is given by

$$p = \alpha - \beta D, \tag{1}$$

[3] Implicitly, there is a numeraire good at the background and this good is produced using labour and a sector specific factor unelastically supplied. Labour is freely mobile between the two sectors (within a country) and the wage rate in terms of the numeraire good is rigid. Labour is the only factor of production in the oligopolistic sectors. Production technologies are of the constant returns to scale type everywhere. Given this framework, for our welfare analysis, we can ignore the numeraire good sector.

where p is price and D is the total demand for the good, which is equal to the sum of output produced by the foreign firm, x_1, and output produced by the domestic firm, x_2, in country 2. That is,

$$D = x_1 + x_2, \tag{2}$$

Profit of a firm, π_i, is given by

$$\pi_i = (p - \kappa_i)x_i, \qquad i = 1, 2, \tag{3}$$

where κ_i is the constant average (marginal) cost of each i firm that is given by

$$\kappa_i = c_i + \mu(\theta_i - z_i), \quad i = 1, 2, \tag{4}$$

where c_i is a constant per unit cost determined by technological and factor market conditions, θ_i is the gross pollution (pollution before abatement), μ is the constant unit cost of abatement,[4] and $z_i \in (0, \theta_i)$ is the maximum quantity of pollution per unit of output that the firms are allowed to emit into the atmosphere.[5]

The firms are assumed to behave in a Cournot-Nash fashion. Hence, profit maximisation yields

$$\beta x_i = p - \kappa_i \quad i = 1, 2 \tag{5}$$

Given the policy decisions of the governments, the equilibrium output of foreign and domestic firms can be found from (5) as

$$x_1 = \frac{\alpha - 2\kappa_1 + \kappa_2}{3\beta} \tag{6}$$

$$x_2 = \frac{\alpha + \kappa_1 - 2\kappa_2}{3\beta} \tag{7}$$

As stated before, we assume that there is unemployment in countries 1 and 2. Following Brander and Spencer (1987), factor input costs are taken to be the income of the factors which would remain unemployed in the absence of the production of the

[4]For simplicity, we assume μ to be the same for the two firms.

[5]Both θ_i's and z_i's are implicitly assumed to be above the level which the World Health Organisation considers to be harmless.

oligopolistic good (see footnote 2). Hence, the welfare levels in country 1 and country 2 are given by W_1 and W_2.

$$W_1 = c_1 x_1 - \phi_1 x_1 z_1 \tag{8}$$

$$W_2 = c_2 x_2 + \pi_2 - \phi_2 x_2 z_2 \tag{9}$$

where ϕ_i is the marginal disutility of pollution.[6] We assume that the profits of FDI are repatriated to the source country. Hence, country 1 benefits from FDI only through the employment generated by foreign firms, but can not exploit any rents from the profits of FDI. The employment benefit is given by the first term on the right hand side of (8). Country 2, on the other hand, benefits from the profits earned by the domestic firm as well as the employment created by export-oriented production. These benefits are given by the first and second terms on the right hand side of (9). However, both the countries dislike pollution that accompanies production, as given by the last terms in the two equations.[7]

Substituting (4) in (6) and (7), and totally differentiating the results we obtain

$$dx_1 = \frac{2\mu}{3\beta}dz_1 - \frac{\mu}{3\beta}dz_2 \tag{10}$$

$$dx_2 = -\frac{\mu}{3\beta}dz_1 + \frac{2\mu}{3\beta}dz_2 \tag{11}$$

The above equations state that each firm will increase (decrease) production if it is allowed to emit more (less) pollution or if the amount of pollution that the rival firm is allowed to emit is reduced (raised).[8]

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[6] The assumption of constancy ϕ_i is made without any loss of generality. If we considered a more general disutility function $\phi_i(x_i z_i)$, the ensuing analysis will go through by replacing ϕ_i by ϕ_i'.

[7] We only consider the case of local pollution. That is, pollution harms only the country which it is generated. Hence, we rule out transboundary pollution. See, for example, Copeland (1996) and Copeland and Taylor (1995) for analysis of transboundary pollution.

[8] Note that we assume the demand function to be linear for analytical simplicity. However, our qualitative results are robust under a more general demand functions. Let $p = f(D)$ be a general inverse demand function. Solving for Cournot-Nash type first-order profit maximisation conditions, and totally differentiating the results one can obtain ($dx_i = -(\mu/f\prime)dz_i - \Delta_i dD$), where ($\Delta_i = 1 + f\prime\prime x_i/f\prime$), and ($i = 1, 2$). In the literature Δ is normally assumed to be positive. This assumption

Totally differentiating the welfare functions we get

$$3\beta \; dW_1 = A_1 dz_1 + A_2 dz_2, \tag{12}$$

$$3\beta \; dW_2 = A_3 dz_1 + A_4 dz_2, \tag{13}$$

where

$$\begin{aligned} A_1 &= [2\mu c_1 - \phi_1(2\mu z_1 + 3\beta x_1)]\,, \\ A_2 &= \mu[\phi_1 z_1 - c_1], \\ A_3 &= \mu[\phi_2 z_2 - c_2 - 2\beta x_2], \\ A_4 &= [2\mu(2\beta x_2 + c_2) - \phi_2(2\mu z_2 + 3\beta x_2)]\,. \end{aligned}$$

We discuss first the effects of each government's environmental policy on the welfare of its own nationals. For example, when country 1 reduces z_1, total pollution in that country is reduced. The reduction in pollution benefits country 1, with the magnitude of this benefit depending on the marginal disutility of pollution in that country. This benefit is given by the last term in A_1 for country 1, while in country 2 it is the last term in A_4. A reduction in z_i $(i = 1, 2)$ also reduces the amount of output produced in country i by increasing the unit costs of production. For country 1, this will increase unemployment. This is given by the first term in A_1. For country 2, a reduction in output will reduce employment and profits. These are given by the first term in A_4 respectively.

Second, we examine the external effects of each government's pollution regulations on the other country's welfare. A reduction in z_1 will create a competitive advantage for the firm in country 2, resulting in an increase in its production. This increase in production in country 2 will have three effects on country 2's welfare through increased level of pollution, employment and profits of the domestic firm, and these are given by the three terms in A_3. A reduction in z_2, on the other hand, has similar effects on country 1's welfare. However, since profits of the foreign firm are repatriated, there are only two effects here.

correspond to the 'normal' case in Seade (1980) and to the strategic substitutes in Bulow *et al* (1985). The stability of the Cournot equilibrium is guaranteed when $(1 + \Delta_1 + \Delta_2)$ is positive.

3 Non-cooperative Solution

In this section, we consider the case where the governments behave in a non-cooperative fashion. We shall find the non-cooperative Nash pollution levels, z_1^N and z_2^N, that the firms are allowed to emit into atmosphere per unit of output.

Setting A_1 and A_4 in (12) and (13) equal to zero, we find the Nash equilibrium values of the two instruments[9]

$$z_1^N = \frac{2\mu c_1 - 3\phi_1 \beta x_1}{2\phi_1 \mu}, \tag{14}$$

$$z_2^N = \frac{2\mu c_2 - \beta x_2(3\phi_2 - 4\mu)}{2\phi_2 \mu}. \tag{15}$$

It is clear from (14) that a sufficient condition for $z_1^N = 0$ is that either the foreign firm is sufficiently efficient or the private cost of abatement is sufficiently small.[10] Similarly, under the concavity of the welfare function ($3\phi_2 > 4\mu$), from (15), $z_2^N = 0$ if either the domestic firm is sufficiently efficient or the private cost of abatement is sufficiently small. In this model a government will impose the most severe restriction possible if either the firm located in that country is very efficient and thus does not generate much employment or if the cost of abatement to the firms is very small. In that case, each firm has to abate all the pollution it creates through production. Throughout this work we will assume that the firms are not very efficient and that the private cost of abatement is sufficiently high so that the pollution allowance levels are positive.

3.1 Comparative Statics

Using the non-cooperative solutions above, we now examine the effects of changes in two parameters on the equilibrium emission levels. The parameters we focus on are the

[9] The second order conditions are $3\beta(\partial^2 W_1/\partial z_1^2 = -4\phi_1\mu < 0,\ 9\beta(\partial^2 W_2/\partial z_2^2 = -4\mu(3\phi_2 - 2\mu) < 0$, while the stability condition is $1/16 < (3\phi_2 - 2\mu)/(3\phi_2 - 4\mu)$. Both the concavity and stability conditions hold if $3\phi_2 > 4\mu$.

[10] Note that if z_1^N in (14) is negative, the optimal policy would be to impose the strictest restriction, i.e., $z_1^N = 0$.

demand parameter α in the consuming country, which is used as a measure for market size, and the per unit gross pollution (pollution before abatement), θ_i $(i = 1, 2)$.

Emission levels and market size:

From the non-cooperative values we get

$$\begin{aligned}\frac{\partial z_1^N}{\partial \alpha} &= -3\frac{(5\phi_2 - 4\mu)}{\mu(45\phi_2 - 28\mu)} < 0 \\ \frac{\partial z_2^N}{\partial \alpha} &= -5\frac{(3\phi_2 - 4\mu)}{\mu(45\phi_2 - 28\mu)} < 0\end{aligned}$$

A decrease in the market size will lead governments to impose less severe emission restrictions. This is because a decrease in market size will decrease the amount of goods produced by both firms. On the other hand, the marginal negative effect on welfare of relaxing the pollution standards is smaller when the amount of output is smaller. Therefore, a decrease in the market size decreases the negative marginal effect of relaxing pollution on welfare of both countries.[11]

Proposition 1 *When there is a decrease in market size, the optimal non-cooperative level of pollution that the firms are allowed to emit will increase in both countries.*

Emission levels and gross pollution:

Differentiating the Nash solutions with respect to per unit gross pollution in country 1 we get

$$\begin{aligned}\frac{\partial z_1^N}{\partial \theta_1} &= 3\frac{(7\phi_2 - 4\mu)}{(45\phi_2 - 28\mu)} > 0 \\ \frac{\partial z_2^N}{\partial \theta_1} &= -2\frac{(3\phi_2 - 4\mu)}{(45\phi_2 - 28\mu)} < 0\end{aligned}$$

An increase in the level of gross pollution by the foreign firm will increase its marginal costs, and therefore reduce its output. To encourage foreign firm to produce more, the country 1 government will find it optimal to allow it to emit more pollution. As

[11] There are no cross effects on welfare of relaxing the pollution standards through employment in country 1, and through employment and domestic profits in country 2 because of the linear specification of the model.

costs in country 1 are risen with an increase in gross pollution, the firm in country 2 receives a competitive advantage. Therefore, the government in country 2 can impose a stricter pollution restriction.

Proposition 2 *An increase in the per unit gross pollution level in a country will increase the optimal non-cooperative level of pollution that the firm in that country is allowed to emit, and reduce the same for its rival in the other country.*

3.2 Reform from a non-cooperative equilibrium

In this subsection we examine the effects on welfare in both countries of a small uniform reduction in the maximum level of pollution which the firms are allowed to emit when the initial levels are set at the non-cooperative level. This can be seen as a multilateral effort to coordinate environmental policies. The uniform permit reduction reform is defined as

$$dz_1 = dz_2 = -\delta \tag{16}$$

Substituting (14) in (12), (15) in (13), and using (16), we obtain

$$\begin{aligned} 2\ dW_1|_{z_1=z_1^N} &= \phi_1 x_1 \delta > 0 \\ 2\ dW_2|_{z_2=z_2^N} &= \phi_2 x_2 \delta > 0 \end{aligned}$$

From above we have

Proposition 3 *Starting from the non-cooperative equilibrium, a uniform reduction in the pollution allowance is strictly Pareto-improving.*[12]

Recall that the non-cooperative equilibrium levels are found by equating A_1 and A_4 to zero. Hence, all that remains are A_2 and A_3, which are the international externalities associated with environmental policies. Although, as explained before,

[12]By strict Pareto improvement, we mean that the welfare levels in country 1 and 2 are higher: we do not take into account the consuming country's welfare.

these externailities are ambiguous in sign in gerenal, when evaluated at the Nash equilibrium, these are unambiguously negative.

We now turn to comparing the levels of restrictions in the two countries under a number of scenarios. To focus our analysis on the role of foreign ownership in one country, we assume that the foreign firms in country 1 and the domestic firm in country 2 employ an identical technology such that $c_1 = c_2 = c$ and $\theta_1 = \theta_2 = \theta$. Second, the marginal disutility of pollution in the two countries is also identical, and hence $\phi_1 = \phi_2 = \phi$. Thus we have

$$c_i = c, \qquad \theta_i = \theta, \qquad \phi_i = \phi, \qquad (i = 1, 2) \tag{17}$$

First of all, we compare the magnitudes of z_1^N relative to z_2^N. Using (17), we find the difference as

$$z_1^N - z_2^N = -\frac{8(\phi\omega + \mu c)}{\phi(45\phi - 28\mu)} < 0$$

where $\omega = (\alpha - \mu\theta - c) = 3\beta x_1|_{z_1=z_2=0} > 0$. Hence, the host country of FDI applies stricter emission standards. This is because of profits generated by the domestic firms in country 2. Recall that the level of pollution permits affects country 1's welfare through the changes in employment and pollution whereas it affects country 2's welfare through the changes in employment, pollution and domestic profits. Formally,

Proposition 4 *In the absence of free entry and exit of foreign firms, when the countries do not cooperate, the FDI-host country applies more severe pollution allowance level than the other country.*

We now turn to the cooperative equilibrium. In order to find the cooperative equilibrium, we define total welfare by adding (12) and (13)

$$3\beta\, dW = (A_1 + A_3)\, dz_1 + (A_2 + A_4)\, dz_2 \tag{18}$$

Setting the coefficients of dz_1 and dz_2 equal to zero, and solving simultaneously for z_1 and z_2, we find the cooperative solutions as[13]

$$z_1^C = \frac{\mu c - \phi(2\beta x_1 + \beta x_2)}{\phi\mu}, \tag{19}$$

$$z_2^C = \frac{\mu c - 2\beta x_2(\phi - \mu) - \phi\beta x_1}{\phi\mu}. \tag{20}$$

We can now find the difference between the cooperative levels by using the explicit solutions of x_1 and x_2:

$$z_1^C - z_2^C = -\frac{\phi\omega + \mu c}{2\phi(3\phi - 2\mu)} < 0$$

Once again, the FDI host country applies stricter rules than the other country.

Proposition 5 *In the absence of free entry and exit of foreign firms, under the cooperative solution the FDI-host country applies more severe environmental standards than the other country.*

We now compare the magnitudes of optimal emission restrictions for the two countries under the cooperative and non-cooperative equilibria. Using the explicit solutions, we obtain

$$z_1^N - z_1^C = \frac{(15\phi - 4\mu)(\phi\omega + \mu c)}{2\phi\mu(45\phi - 28\mu)} > 0$$

$$z_2^N - z_2^C = \frac{[\phi(45\phi - 39\mu) + 4\mu^2](\phi\omega + \mu c)}{2\phi\mu(45\phi - 28\mu)(3\phi - 2\mu)} > 0$$

That is, the governments apply stricter environmental standards when they cooperate. This is because the international externalities are negative. Stating formally,

Proposition 6 *In the absence of free entry and exit, the governments impose more restrictive environmental standards under the cooperative solution than that under the non-cooperative solution.*

[13] For total welfare to be concave in z_1 and z_2, we must have $9\beta W_{z_1 z_1} = -2\mu(6\phi - \mu) < 0$, $9\beta W_{z_2 z_2} = -4\mu(3\phi - 2\mu < 0$, $9\beta^2 \left[W_{z_1 z_1} W_{z_2 z_2} - W_{z_1 z_2}^2\right] = 4\mu^2\phi(3\phi - 2\mu) > 0$, and a stable equilibrium requires $(3\phi - 2\mu)/(6\phi - \mu) < 2$. Both the concavity and the stability conditions above are satisfied if $3\phi > 2\mu$.

We now assume that the cooperative solutions are restricted to be uniform. Setting $z_1 = z_2 = z^U$ and reorganising (18) we have

$$3\beta\ dW|_{z_1=z_2=z^U} = (A_1 + A_2 + A_3 + A_4)\ dz \tag{21}$$

Setting the coefficient of dz equal to zero we obtain the uniform emission level as[14]

$$z^U = \frac{2\mu(c + \beta x_2) - 3\phi\beta(x_1 + x_2)}{2\phi\mu} \tag{22}$$

If either the private cost of abatement is sufficiently small or if the foreign firms are sufficiently efficient and the marginal disutility of pollution is higher than the private cost of abatement (i.e., $\phi > \mu$) then $z_U = 0$.

Next we analyse the magnitude of the uniform level of emission standards relative to cooperative solution by using the explicit solutions for optimal pollution levels for both countries.

$$\begin{aligned} z_1^C - z^U &= -\frac{\phi\omega + \mu c}{2\phi(6\phi - \mu)} < 0 \\ z_2^C - z^U &= \frac{(\phi\omega + \mu c)(3\phi + \mu)}{2\phi(3\phi - 2\mu)(6\phi - \mu)} > 0 \end{aligned}$$

where $6\phi > \mu$ and $3\phi > 2\mu$ from the concavity conditions. Hence, $z_2^C > z^U > z_1^C$. When the policies are determined uniformly, the pollution allowance level in country 1 (country 2) is less (more) severe than its cooperative level. Furthermore, using the explicit solutions, one can also show that the uniform pollution allowance level is always stricter than the corresponding non-cooperative levels. That is,

$$\begin{aligned} z_1^N - z^U &= \frac{[\phi(45\phi - 42\mu) + 16\mu^2](\phi\omega + \mu c)}{\phi\mu(45\phi - 28\mu)(6\phi - \mu)} > 0 \\ z_2^N - z^U &= \frac{[\phi(45\phi + 6\mu) + 8\mu^2](\phi\omega + \mu c)}{\phi\mu(45\phi - 28\mu)(6\phi - \mu)} > 0 \end{aligned}$$

Stating the above results formally,

Proposition 7 *In the absence of free entry and exit, the optimal uniform level of pollution allowance is always less than the optimal non-cooperative levels and is between the optimal cooperative levels for country 1 and country 2.*

[14]Concavity of the welfare function requires $9\beta W_{zz} = -2\mu(6\phi - \mu) < 0$.

4 Free entry and exit of FDI

In this section we extend the model developed in the previous sections by allowing the number of foreign firms to be endogenous. We assume that there are now n identical foreign firms from the rest of the world which operate in country 1.[15] It is assumed that country 1 is small in the market for FDI. Hence, the foreign firms will move into (out of) country 1 if the profits they make in country 1 are larger (smaller) than the reservation profit, $\bar{\pi}$, that they can make in the rest of the world. Therefore, in the FDI equilibrium we must have

$$\pi_1 = \bar{\pi}. \tag{23}$$

The total output in this case is defined as

$$D = nx_1 + x_2. \tag{24}$$

Some of the key variables can be solved as:

$$n = \frac{\alpha - 2\kappa_1 + \kappa_2}{\sqrt{\bar{\pi}}\sqrt{\beta}} - 2, \tag{25}$$

$$x_1 = \frac{\alpha - 2\kappa_1 + \kappa_2}{\beta(2+n)} = \frac{\sqrt{\bar{\pi}}}{\sqrt{\beta}}, \tag{26}$$

$$x_2 = \frac{\sqrt{\bar{\pi}}\sqrt{\beta} + \kappa_1 - \kappa_2}{\beta}. \tag{27}$$

From the above we obtain

$$dn = \frac{2\mu}{\sqrt{\bar{\pi}}\sqrt{\beta}}dz_1 - \frac{\mu}{\sqrt{\bar{\pi}}\sqrt{\beta}}dz_2, \tag{28}$$

$$dx_1 = 0, \tag{29}$$

$$dx_2 = -\frac{\mu}{\beta}dz_1 + \frac{\mu}{\beta}dz_2. \tag{30}$$

Equation (28) states that since there is free entry and exit of FDI, a reduction in the number of emission permits allocated to the the domestic firm in country 2 or

[15] Unfortunately, it is not possible to endogenise the numbers of firms in both countries as then one group of firms -the ones with higher marginal costs- will be forced out of the market. One way out could be to relax the assumption that the goods produced by the two group of firms are homogeneous as was done in Lahiri and Ono (1998b).

an increase in emission permission allocated to the foreign firm will encourage more foreign firms to enter country 1. The domestic firm in country 2 will increase (decrease) production if it is allowed to emit more (less) or if the amount of pollution that the foreign firm is allowed to emit is reduced (raised) (equation (30)). Because of free entry and exit and the linearity of demand, the output of a foreign firm does not change with the policy instruments.

Multiplying the right hand side of country 1's welfare function (equation (8)) by n and totally differentiating the resulting equation and country 2's welfare function (equation (9)), we get

$$\beta\, dW_1 = A_5 dz_1 + A_6 dz_2, \tag{31}$$

$$\beta\, dW_2 = A_7 dz_1 + A_8 dz_2, \tag{32}$$

where

$$\begin{aligned} A_5 &= \left[2\mu c - \phi(2\mu z_1 + \beta x_1 n)\right], \\ A_6 &= \mu[\phi z_1 - c], \\ A_7 &= \mu[\phi z_2 - c - 2\beta x_2], \\ A_8 &= \left[\mu(2\beta x_2 + c) - \phi(\mu z_2 + \beta x_2)\right]. \end{aligned}$$

The direct and external effects of each government's environmental policy on the welfare of the two countries are similar to those in the case where there is no entry and exit. However, the effects on the FDI production of a reduction in per unit pollution allowance will be due to the changes in the number of foreign firms. For example, a reduction in z_i $(i = 1, 2)$ reduces the total output produced in country i. There will be less foreign firms investing in country 1, while the firm in country 2 will produce less.

Setting A_5 and A_8 equal to zero,[16] we find

$$\hat{z}_1^N = \frac{2\mu c - \phi\beta x_1 n}{2\phi\mu} \tag{33}$$

[16]For the concavity, we must have $\beta(\partial^2 W_1/\partial z_1^2) = -4\phi\mu < 0,\ \beta(\partial^2 W_2/\partial z_2^2) = -2\mu(\phi - \mu) < 0$, while the stability condition is $1/4 < 2(\phi-\mu)/(\phi-2\mu)$. Both the concavity and the stability conditions hold if $\phi > 2\mu$.

$$\hat{z}_2^N = \frac{\mu c - \beta x_2(\phi - 2\mu)}{\phi\mu} \tag{34}$$

where ($\phi > 2\mu$) from the concavity condition above. We can now examine the relative magnitude of non-cooperative pollution permit levels by subtracting (34) from (33).

$$\hat{z}_1^N - \hat{z}_2^N = \frac{3\sqrt{\bar{\pi}}\sqrt{\beta}(\phi - 2\mu) - (\phi\hat{\omega} + \mu c)}{\mu(7\phi - 6\mu)} \tag{35}$$

where $\hat{\omega} = (\alpha - c - \mu\theta - 2\sqrt{\bar{\pi}}\sqrt{\beta}) = \sqrt{\bar{\pi}}\sqrt{\beta}n|_{z_1=z_2=0} > 0$. Since $\phi > 2\mu$, it follows from (35) that $\hat{z}_1^N < \hat{z}_2^N$ if $\bar{\pi}$ is sufficiently small. When the reservation profit is very small, there will be many foreign firms investing in country 1 as they have less profitable opportunities in the rest of the world. Since there is a large supply of FDI, the government in country 1 will be able to impose more severe environmental regulations. On the other hand, when the reservation profit is sufficiently large, there will be few foreign firms entering country 1. With a small supply of FDI, the government in country 1 will try to attract the foreign firms by imposing less severe environmental regulation. Recall that in the absence of free entry and exit country 1 unambiguously imposes more severe environmental standards than country 2, as pollution is the main concern for country 1. Here, however, country 1 is more concerned with attracting FDI. In particular, it imposes less severe policies when the supply of FDI is small. Stating the above results formally,

Proposition 8 *When the governments set non-cooperative policies, in the presence of free entry and exit in the FDI market, the FDI host country will impose stricter pollution restrictions than the other country if the reservation profit is sufficiently small.*

We now turn to cooperative equilibrium. In order to find the cooperative equilibrium, we define total welfare by adding (31) and (32);

$$\beta\ dW = (A_5 + A_7)\ dz_1 + (A_6 + A_8)\ dz_2. \tag{36}$$

Setting the coefficients of dz_1 and dz_2 equal to zero in (36) and solving them simultaneously, we find the cooperative solutions as[17]

$$\hat{z}_1^C = \frac{\mu c - \phi(\beta x_2 + \beta x_1 n)}{\phi\mu}, \tag{37}$$

$$\hat{z}_2^C = \frac{\mu c - 2\beta x_2(\phi - \mu) - \phi\beta x_1 n}{\phi\mu}. \tag{38}$$

Subtracting (37) from (38) we get

$$\hat{z}_1^C - \hat{z}_2^C = \frac{\beta x_2(\phi - 2\mu)}{\phi\mu} \tag{39}$$

From (39) it is clear that $\hat{z}_1^C > \hat{z}_2^C$ if and only if $\phi > 2\mu$. When the two countries cooperate the difference between the governments' pollution allowance levels depend on the magnitude of marginal disutility of pollution relative to the marginal private cost of abatement. If the disutility from pollution, ϕ, is very large the government in country 2 applies more severe emission standards than country 1. Since there is no entry and exit in country 2, when the two governments cooperate the government in country 2 will be able to impose more severe environmental standards. In this case, the government of country 2 applies more (less) severe policies if the marginal disutility of pollution is sufficiently large (small).

Proposition 9 *When the two countries cooperate, in the presence of free entry and exit in the FDI market, the FDI-host country applies less severe pollution standards than the other country if the marginal disutility of pollution is sufficiently small.*

Before proceeding to the case where the governments determine a uniform equilibrium pollution allowance, we shall find the difference in permitted emission levels between the cooperative and non-cooperative cases. Using the explicit solutions, and imposing the concavity condition for non-cooperative and cooperative equilibria (($\phi > \mu$) and ($\phi > 2\mu$), respectively), we obtain

$$\hat{z}_1^N - \hat{z}_1^C = \frac{\phi\sqrt{\pi}\sqrt{\beta}(5\phi - 2\mu) + (3\phi - 2\mu)(\phi\hat{\omega} + \mu c)}{2\phi\mu(7\phi - 6\mu)} > 0$$

[17]For total welfare to be concave in the two instruments, we must have $\beta W_{z_1 z_1} = -2\mu(2\phi - \mu) < 0$, $\beta W_{z_2 z_2} = -2\mu(\phi - \mu) < 0$, $\beta^2 \left[W_{z_1 z_1} W_{z_2 z_2} - W_{z_1 z_2}^2\right] = 4\mu^2\phi(\phi - \mu) > 0$, and for a stable equilibrium, we must have $(\phi - \mu)/(2\phi - \mu) < 1$. Both the concavity and the stability conditions are satisfied if $\phi > \mu$.

$$\hat{z}_2^N - \hat{z}_2^C = \frac{[\phi(5\phi - 7\mu) + 2\mu^2](\phi\hat{\omega} + \mu c) + [\phi(6\phi - 9\mu) + 2\mu^2]\phi\sqrt{\pi}\sqrt{\beta}}{2\phi\mu(7\phi - 6\mu)(\phi - \mu)} > 0$$

The above equations suggest that when the governments cooperate, the maximum pollution per unit of output that the firms are allowed to emit is less than that when the governments do not cooperate. As in the case with no entry and exit the governments apply stricter environmental standards if they cooperate. Stating formally,

Proposition 10 *When the number of foreign firms is endogenous, the governments impose more restrictive environmental standards under the cooperative solution than that under the non-cooperative solution.*

Finally, turning to the case where the cooperative solution is restricted to be uniform, we have

$$\beta\ dW|_{z_1=z_2=z^U} = (A_5 + A_6 + A_7 + A_8)dz \tag{40}$$

Setting the coefficient of dz equal to zero we get

$$\hat{z}^U = \frac{\mu c - \phi\beta(x_1 n + x_2)}{\phi\mu} \tag{41}$$

Using the explicit solutions for z^U and z_1^C one can show that

$$\hat{z}^U = \hat{z}_1^C$$

Formally,

Proposition 11 *In the presence of free entry/exit in the FDI market,* $\hat{z}^U = \hat{z}_1^C$.

The maximum level of permitted per unit pollution in country 1 is the same in the cooperative and uniform solutions. Proposition 3.11 implies that country 2 will impose a more (less) restrictive emission standard under the uniform policy with cooperation if the marginal disutility of pollution is sufficiently large (small). Recall that in the case with no entry and exit of FDI $z_2^C > z^U > z_1^C$.

Finally, subtracting $\hat{z}^U$ from the optimal non-cooperative levels, $\hat{z}_1^N$ and $\hat{z}_2^N$, and using the explicit solutions, one can show that

$$\begin{aligned}\hat{z}_1^N - \hat{z}^U &= \frac{\phi\sqrt{\pi}\sqrt{\beta}(5\phi - 2\mu) + (3\phi - 2\mu)(\phi\hat{\omega} + \mu c)}{2\phi\mu(7\phi - 6\mu)} > 0 \\ \hat{z}_2^N - \hat{z}^U &= \frac{-\phi\sqrt{\pi}\sqrt{\beta}(\phi - 10\mu) + (5\phi - 2\mu)(\phi\hat{\omega} + \mu c)}{2\phi\mu(7\phi - 6\mu)} > 0\end{aligned}$$

Note that $(5\phi-2\mu)\phi\hat{\omega} > \phi\sqrt{\pi}\sqrt{\beta}(\phi-10\mu)$ for any values of n, since $\hat{\omega} = \sqrt{\pi}\sqrt{\beta}n|_{z_1=z_2=0}$. As before the optimal uniform level of pollution allowance is unambiguously less than the individual optimal non-cooperative levels. Formally,

Proposition 12 *In the presence of free entry and exit of foreign firms, when the governments determine the policies uniformly, they impose more restrictive emission standards under the uniform solution than that under the non-cooperative solution.*

5 Conclusion

We develop a partial equilibrium model of FDI and analyse the interaction between the environmental standards and FDI. We begin our analysis with two firms (one from each country) which compete to export a homogeneous good to a third country. The firm located in country 1 is foreign owned while the firm located in country 2 is owned by domestic producers. We then extend the model to allow the number of foreign firms to be endogenous. The FDI equilibrium is determined by equating the profits of the foreign firms to an exogenous level representing the reservation level of profits which the foreign firms could obtain if they invested in alternative countries. Pollution occurs during production by both types of firms, and both firms possess a technology for abating pollution they generate. The governments in the two countries can force the firms to decrease the level of pollution they generate through quantitative restrictions on pollution. Any quantity restrictions on pollution affect country 1 welfare through effects on employment and pollution, while country 2 is affected through change in the profits of the domestic firms as well as employment and pollution.

Using the specification above, we examine the equilibrium levels of quantity restrictions on pollution when the governments act in a non-cooperative and cooperative fashion. We find that the non-cooperative equilibrium always generates a higher level of pollution per unit of output. Furthermore, it is found that starting from the non-cooperative equilibrium, a small uniform reduction in the pollution allowance is strictly Pareto-improving. We find that the above results also hold in both the benchmark and general model.

When there is no entry and exit in the FDI market, the FDI host country always sets more severe policy than the other country, as the government in the former does not have to consider the effect on the outflow of FDI and the level of profits. However, the relative magnitude of quantity restrictions on pollution between the two countries is ambiguous in the presence of free entry and exit of FDI. In particular, we find that when the pollution policies are set non-cooperatively, and the number of foreign firms is endogenous, the FDI-host country will set a higher pollution allowance if the reservation profit is large (i.e., if there are few foreign firms). In the cooperative equilibrium (with endogenous number of foreign firms), our results suggest that country 2 sets a lower (higher) pollution allowance if the marginal disutility of pollution is sufficiently high (low).

When the number of foreign firms is exogenous, the optimal uniform restriction on pollution is set in between the cooperative levels of the two countries. With free entry and exit of FDI, however, the maximum level of permitted per unit pollution in FDI-host country is the same in the cooperative equilibrium whether or not the solution is restricted to be uniform.

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