

# Foreign Direct Investment and the Choice of Environmental Policy

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## Abstract

We use an oligopoly model of intra-industry trade to examine the implications of foreign direct investment for the pollution haven hypothesis and environmental policy. Countries which lower environmental standards to be more competitive in world markets generate pollution havens if environmental policy is fixed. However, if FDI is a viable option as a mode of entry, profit-shifting considerations weaken in favour of environmental considerations and FDI-recipients tighten environmental policy, weakening the pollution haven hypothesis by reducing incentives to relocate production. Interestingly, FDI may still occur in spite of the stricter standards in order to level the playing field. We derive conditions under which the FDI-receiving country has an incentive to manipulate its environmental standard to prevent or attract FDI, potentially eliminating or creating pollution havens. Without manipulation of standards, FDI leads to improvements in world pollution levels. However, when countries manipulate their standards, FDI can lead to a dirtier environment if the two countries are substantially different in their valuation of environmental damages.

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# 1 Introduction

As the global economy has become more integrated, flows of foreign direct investment (FDI) have increased significantly. In 2003, 64,000 multinationals controlled more than 870,000 foreign affiliates worldwide (UNCTAD, 2008) and their sales exceeded \$18 trillion (compared to world exports of \$8 trillion). Cognizant of this trend, policymakers and researchers have focused on the welfare implications of FDI and on identifying economic variables that are instrumental in FDI decisions. Opponents to international trade and investment flows frequently argue that globalization and the presence of multinationals cause too lax environmental policies and “pollution havens” to emerge (Newell, 2001; Cole et al., 2006). According to the Pollution Haven Hypothesis (PHH), differences in pollution regulation across countries constitute a significant determinant of trade patterns and FDI/capital flows as firms in highly pollution-intensive industries have incentives to relocate their operations in countries with less stringent environmental standards. In Eskeland and Harrison (2003), the PHH is best seen as a corollary to the theory of comparative advantage: if it is more costly to conform to more stringent environmental standards at home, profit-maximizing firms would want to relocate their production activities.

As noted in Taylor (2004), a necessary, although not sufficient, condition for the PHH is the presence of a “pollution haven effect” which results when a tightening of environmental regulation deters exports (or stimulates imports) of dirty goods. While support for the latter is provided in several empirical studies, the evidence for or against the former (that is, the PHH) is rather limited. Although there exists a growing body of evidence in support of a significant link between the stringency of pollution regulations and the location of foreign direct investment and the size of net trade flows in U.S. manufacturing industries (List and Co, 2000; Keller and Levinson, 2002; Ederington and Minier, 2003), thus suggesting a fairly strong response by firms to differences in environmental regulation, there is little evidence that regulatory differences constitute the most relevant determinant of trade flows as the PHH predicts. Various reasons why this is the case from an empirical viewpoint have been proposed (e.g., data, measurement of environmental stringency); however, reasons why the PHH may fail theoretically have not received much attention.

The focus of existing theoretical and empirical literatures is mostly on the effects of local environmental policies on investment flows (List and Co, 2000; Keller and Levinson, 2002; Javorcik and Wei, 2004; Xing and Kolstad, 2002). Most closely related to our paper is Markusen et al. (1993, 1995). In the 1993 article, a single active regional government influences the plant location of a single firm with increasing returns to scale and local pollution; in the 1995 article, the plant location problem is extended to the case in which both regional governments are active in policy setting. Several extensions to this framework

have been examined, including zero transportation costs (Hoel, 1997). Other modifications include policy commitment/time consistency (Ulph and Valentini, 2001; Petrakis and Xepapadeas, 2003) and asymmetric relocation information (Greaker, 2003).<sup>1</sup> Our analytical framework differs from these models in several important ways. First, rather than examining the impact of environmental policy on the location decision of production, we focus on the impact of the option for FDI (potential relocation of production) on the choice of environmental policy. Second, instead of a single firm choosing to locate in both regions (multi-plant), one region, or no region, we assume two independent firms producing for (and competing in) the two markets. Third, we do not rely on increasing returns to scale or shipping costs to influence the location (FDI) decision. Finally, instead of two symmetric regions selecting environmental policy, we rely on the two countries placing different weights on environmental damages to generate environmental policy differences in the absence of FDI (that is, to induce a PHH incentive for FDI). Another related paper is Cole et al. (2006), in which a model of political economy with lobbying and government corruption is employed to explicitly examine the relationship between FDI and environmental policy. While the effect on environmental policy of an additional (foreign) producer is considered, the entry decision of the foreign firm is exogenous; we, on the other hand, are interested in the choice of FDI and how this choice is manipulated through environmental policy, depending on the external benefits of FDI. While the key proposition in Cole et al. that foreign entry results in stricter environmental policy (when corruption is low) is confirmed in most of the cases we cover, we encounter cases in which FDI does not occur but environmental policy is still affected.

In the present paper, we aim at filling the gap in the literature by addressing the following questions: (1) Under what conditions do differences in environmental regulation across countries give firms in countries with more stringent standards incentives to engage in FDI in countries with less stringent standards (this question is directly related to the PHH)? (2) How do these incentives affect local environmental policy and welfare in recipient countries? (3) Under what circumstances would an FDI-recipient country choose to tighten its environmental policy in response to FDI? (4) If this tightening occurs, would the recipient country ever select an environmental standard that is tighter than the standard of the source country (that is, would the recipient ever become more “green” than the originally green country)? (5) If FDI reduces the welfare of the recipient country, would the recipient country manipulate its standard to prevent FDI? (6) More generally, under what conditions would the recipient country adjust its emission standard to attract FDI when the source country would prefer exporting and to prevent FDI when the source country would

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<sup>1</sup> Although the threat is present, relocation never occurs in Greaker (2003).

prefer engaging in FDI? (7) What is the impact of FDI on the state of the environment worldwide and in the FDI-recipient country when FDI is either induced or prevented and when it is not?

To answer the above questions, we use a two-country oligopoly model of intra-industry trade. As in the perfectly competitive model employed in Copeland and Taylor (1994), we assume pollution to be purely local and allow for a technology that abates emissions of pollution. Both countries have the same production and abatement technologies. In order to examine the implications of FDI, we consider a three-stage game. In the first stage, countries simultaneously decide their environmental policy, choosing the emission standards for local firms that maximize welfare defined as the sum of consumer surplus and producer surplus less environmental damages. Each country takes into account environmental damages when setting environmental policy, but the two countries differ in the weight they assign to environmental damage.<sup>2</sup> The second stage of the game involves the firm's decision about whether to serve foreign markets through export or FDI. In this setup, the firm in the country with more stringent environmental standards could move production to the country with more lax standards, depending on the benefits of such a move relative to the cost of setting up a foreign plant.<sup>3</sup> Finally, firms engage in Cournot competition in the product markets. In order to maintain the focus of the analysis on the implications of asymmetric emission standards for foreign direct investment, we ignore trade policy.

In the absence of FDI, the country which places less emphasis on environmental damage has an incentive to lower environmental standards to become more competitive in world markets; however, once FDI is available as a mode of entry, the country is confronted with two conflicting effects of FDI. On one hand, FDI has a positive effect through greater local production/consumption associated with lower domestic prices (higher consumer surplus) and may generate external benefits. On the other hand, FDI has a negative effect through lower profits for the domestic firm due to a loss in competitive advantage (lower producer surplus) and additional environmental damages from greater local production. If the home country assigns a higher weight on environmental damage than the foreign country does, the former can be considered, in the absence of an FDI option, as the more environmentally friendly or “green” country while the latter is the less environmental friendly or “grey” country. As the home country becomes more environmentally sensitive (as its weight on environmental damage increases), it chooses more stringent emission standards while the foreign country chooses less stringent standards.

We first consider a traditional PHH case in which the foreign country does not alter its emission standard

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<sup>2</sup>We consider two similar countries to avoid non-environmental policy related incentives for FDI. The model is thus best suited for the analysis of the impact of FDI on policy setting among equally industrialized countries rather than between North and South.

<sup>3</sup>We ignore the possibility of reciprocal FDI and focus on the FDI decision of the home firm.

in response to FDI. Not surprisingly, we show that, as long as the fixed cost of having an additional plant is sufficiently low and abatement is costly, the home firm facing a less stringent environmental standard abroad has incentives to relocate its production to the foreign country (the traditional PHH case). We then allow for the possibility that the host country is able to respond to FDI and examine the Subgame Perfect Nash Equilibria (SPNE) under various conditions. When FDI occurs, the foreign country has two active producers within its borders, and the relocated home firm faces the same standard as the foreign firm. Thus, the profit-shifting motive disappears while the environmental damage effect widens and the foreign country tightens its emission standard. When the two countries are sufficiently similar in weighing environmental damages, the “grey” country (foreign country) can become greener than the originally “green” country (home country). More interestingly, there are cases in which the home firm chooses to engage in FDI (rather than to export) in the foreign country even though the foreign emission standard is stricter than its own standard under the export case. Intuitively, as countries become more asymmetric in their environmental friendliness, the gap between their standards increases under export; as long as the asymmetry is not too large, the home firm would prefer to relocate to the foreign country in order to *level the playing field* even if relocation entails facing a tighter standard.<sup>4</sup>

When allowing the foreign country to respond to the home firm’s FDI, we later consider the question of whether the foreign country can induce export (FDI) via preventing (attracting) FDI by adjusting its standard and, if so, whether this move leads to higher welfare in the foreign country and a cleaner environment worldwide. We obtain that, when the extra weight the home country assigns to environmental damage is low and the benefit the foreign country derives from the home country’s FDI is high, the foreign country is better off inducing the home firm to engage in FDI by increasing its emission standard above the level prevailing under export; when the extra weight is high and the benefit is low, the foreign country is better off inducing the home firm to export by lowering its standard below the level prevailing under FDI. Relative to the case in which environmental policy is not adjusted, pollution havens that would have existed do not come about when FDI is prevented while other pollution havens that would have not existed are generated when FDI is attracted.

From a purely environmental perspective, we show that, relative to the export case, the home firm’s FDI results in two counteracting effects in the foreign country: an *emission standard effect* which amounts to a reduction in emission standards and a *scale effect* which amounts to an increase in output. As the former effect dominates the latter (given the convexity of costs/damages), FDI leads to a cleaner environment in

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<sup>4</sup>This is similar to strategic investment to raise a rival’s costs, as in Salop and Scheffman (1983). Here, the intention is not to increase the rival’s abatement cost (it may in fact lower it) but to eliminate the gap between the costs of the two firms.

the foreign country (and thus worldwide) relative to the export case. However, when the foreign country manipulates standards to either prevent or induce FDI, a dirtier world environment can result when FDI is induced if the two countries do not differ substantially in their valuation of environmental damage. Relative to the FDI case, a cleaner environment obtains when export is induced if the two countries differ substantially in their valuation of environmental damage.

## 2 Model

We develop an oligopoly model of trade with two countries ( $h$  for home and  $f$  for foreign) and two goods ( $x$  and  $y$ ). Good  $y$  is the numeraire good produced under perfect competition with a constant-returns-to-scale technology. There is no pollution associated with the production of good  $y$ . Good  $x$ , the polluting (dirty) good, is produced by a single profit-maximizing firm in each country at zero marginal cost. For convenience, we refer to home (foreign) country's monopolist as firm  $h$  ( $f$ ).

We assume that preferences over the two goods are quasi-linear and the inverse demand for good  $x$  in each country is linear, that is,

$$p_i(x_i) = \alpha - \sum_{z=h,f} x_{zi}, \quad (1)$$

where  $x_i$  denotes the total quantity of good  $x$  sold in country  $i$  :  $x_i = \sum_{z=h,f} x_{zi}$ ,  $p_i$  denotes the price of good  $x$  in country  $i$ , and  $x_{zi}$  denotes the output sold by country  $z$ 's firm in country  $i$ . Firm  $i$ 's total production is made of its sales in the domestic market denoted by  $x_{ii}$  and in the foreign market denoted by  $x_{ij}$  with  $i \neq j$ . Firms compete in quantities (Cournot) in each market. For simplicity, we assume that each unit of  $x$  produced generates one unit of pollution and that, as in Copeland and Taylor (1994), pollution is purely local. Moreover, abatement is possible but costly. Specifically, if a government imposes a cap on the emissions of firm  $i$ , denoted  $e_i$ , the cost of meeting this target is

$$C_i(a_i) = \frac{a_i^2}{2}, \quad (2)$$

where  $a$  represents abatement which is equal to the difference between production and the appropriate emission standard or

$$a_i = \max \left( 0, \sum_{j=h,f} x_{ij} - e_i \right). \quad (3)$$

Environmental damages are quadratic in unabated local emissions and equal to

$$\Psi_i = \frac{1}{2} e_i^2. \quad (4)$$

To examine the implications of FDI access, we consider a three-stage game. In the first stage, countries simultaneously decide over their environmental policy, choosing the welfare-maximizing emission standards for local firms. Welfare is defined as the sum of consumer surplus ( $CS$ ) and producer surplus ( $PS$ ) less environmental damages ( $\Psi$ ). To differentiate between the two countries in terms of their environmental attitude so that they select distinct emission standards, we assume that the home country places heavier emphasis on environmental damages in its welfare.<sup>5</sup> Hence, the welfare of the home country is

$$W_h(\mathbf{e}) \equiv CS_h(\mathbf{e}) + \sum_{j=h,f} \pi_{hj}(\mathbf{e}) - (1+w)\Psi_h(\mathbf{e}) \quad (5)$$

whereas the welfare of the foreign country is

$$W_f(\mathbf{e}) \equiv CS_f(\mathbf{e}) + \sum_{j=h,f} \pi_{fj}(\mathbf{e}) - \Psi_f(\mathbf{e}), \quad (6)$$

where  $\mathbf{e} = [e_h, e_f]$  is the vector of emission standards,  $w > 0$  captures the additional value that the home country places on the environment, and  $\pi_{ij}$  denotes the profit of firm  $i$  in country  $j$ .

The initial game setup is illustrated in Figure 1a. In the second stage of the game, firm  $h$  decides whether to serve the foreign market through export or FDI. In this setup, the firm in the country with a more stringent environmental standard could move production to the country with a more lax standard, depending on the benefit of such a move relative to the cost of setting up a foreign plant, which we assume to be fixed at  $F$ . As pre-commitment and time consistent policies have previously been compared in Ulph and Valentini (2001) and Petrakis and Xepapadeas (2003), we assume for the most part the latter (except when examining the benchmark of no policy reaction/adjustment). Finally, in the third stage, firms engage in Cournot competition in the two product markets. We obtain the subgame perfect Nash equilibrium (SPNE) by backward induction.

### 3 Environmental Policy and Welfare under Export

To find the Subgame Perfect Nash Equilibria (SPNE), it is necessary to determine the payoffs to the countries and firms from FDI and export. To begin, we consider the case where the home firm exports rather than relocates. This case further serves as a benchmark to study the implications of FDI for strategic environmental policy and social welfare. Since each firm produces within its own country, it is subjected to the local emission standard. Hence, firm  $i$  faces an endogenously determined emission standard  $e_i$  and

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<sup>5</sup>We would have qualitatively similar results by assuming that the two countries have different weights on producer surplus. However, as our focus is on environmental policy, how it responds to FDI, and how it can be manipulated to attract or prevent FDI, we maintain the assumption that the two countries differ in their environmental awareness.

the amount of pollution it abates is

$$a_i = \sum_{j=h,f} x_{ij} - e_i, \quad (7)$$

so that its profit is

$$\pi_i = \sum_{j=h,f} p_j x_{ij} - \frac{1}{2} \left( \sum_{j=h,f} x_{ij} - e_i \right)^2, \quad i = h, f. \quad (8)$$

It is immediate that the marginal cost of abatement is equal to abatement. We note that, in order to maintain the focus of our analysis on the implications of asymmetric emission standards for foreign direct investment, we ignore trade policy.<sup>6</sup> We also ignore local taxation of profits, unlike Greaker (2003), so profits return to country of firm ownership.

Given the emission standards  $e_h$  and  $e_f$ , the profit-maximizing output choices must satisfy

$$\begin{aligned} \frac{\partial \pi_i}{\partial x_{ii}} &= \alpha - 3x_{ii} - x_{ji} - x_{ij} + e_i = 0 \\ \frac{\partial \pi_i}{\partial x_{ij}} &= \alpha - 3x_{ij} - x_{jj} - x_{ii} + e_i = 0, \quad i, j = h, f. \end{aligned} \quad (9)$$

We simultaneously solve the above conditions to obtain the Cournot-Nash equilibrium in the export scenario, namely,

$$x_{ii} = x_{ij} = \frac{3\alpha + 4e_i - e_j}{15} \quad \text{and} \quad p_i = \frac{3\alpha - e_i - e_j}{5}, \quad (10)$$

and the following comparative statics

$$\frac{\partial x_{ii}}{\partial e_i} = \frac{\partial x_{ij}}{\partial e_i} = \frac{4}{15} > 0 \quad \text{and} \quad \frac{\partial x_{ii}}{\partial e_j} = \frac{\partial x_{ij}}{\partial e_j} = -\frac{1}{15} < 0, \quad (11)$$

for  $i, j = h, f$ . Thus, firm  $i$ 's total output increases with its own emission standard while it decreases with its rival's emission standard. Moreover, the effect on own output dominates the effect on rival output so that total output sold (price) in a country rises (falls) as either country weakens its standard, that is,

$$\sum_{z=h,f} \frac{\partial x_{zi}}{\partial e_i} = \sum_{z=h,f} \frac{\partial x_{zj}}{\partial e_j} = \frac{1}{5} > 0 \quad \text{and} \quad \frac{\partial p_i}{\partial e_i} = \frac{\partial p_i}{\partial e_j} = -\frac{1}{5} < 0. \quad (12)$$

With the equilibrium behavior of firms as above described, we next examine the first-stage welfare maximization problem governments face to determine the non-cooperative emission standards, that is,

$$\max_{e_h} W_h(\mathbf{e}) = \frac{x_h(\mathbf{e})^2}{2} + \sum_{j=h,f} p_j(\mathbf{e}) x_{hj}(\mathbf{e}) - \frac{1}{2} \left( \sum_{j=h,f} x_{hj}(\mathbf{e}) - e_h \right)^2 - \frac{(1+w)e_h^2}{2} \quad (13)$$

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<sup>6</sup> Inclusion of tariffs would provide countries with an additional incentive for FDI (i.e., tariff jumping) that would cloud the analysis of FDI decisions resulting from differences in environmental policies.

and

$$\max_{e_f} W_f(\mathbf{e}) = \frac{x_f(\mathbf{e})^2}{2} + \sum_{j=h,f} p_j(\mathbf{e})x_{fj}(\mathbf{e}) - \frac{1}{2} \left( \sum_{j=h,f} x_{fj}(\mathbf{e}) - e_f \right)^2 - \frac{e_f^2}{2}. \quad (14)$$

The first-order conditions for the above problems yield

$$\frac{\partial W_i}{\partial e_i} = \theta + e_i \frac{\partial^2 W_i}{\partial e_i^2} + e_j \frac{\partial^2 W_i}{\partial e_i \partial e_j}, \quad i, j = h, f \quad \text{and} \quad i \neq j, \quad (15)$$

where  $\theta = \frac{38\alpha}{75} > 0$ , and the second-order conditions are satisfied as

$$\frac{\partial^2 W_h}{\partial e_h^2} = \frac{\partial^2 W_f}{\partial e_f^2} - w = -\frac{313}{225} - w < 0. \quad (16)$$

We thus have that  $e_i$  and  $e_j$  are strategic substitutes as

$$\frac{\partial^2 W_i}{\partial e_i \partial e_j} = -\frac{23}{225} < 0. \quad (17)$$

Combining the above two first-order conditions, we obtain the negatively sloped reaction functions in emission standards, that is,

$$e_i = -\frac{\theta + e_j \frac{\partial^2 W_i}{\partial e_i \partial e_j}}{\frac{\partial^2 W_i}{\partial e_i^2}}, \quad i, j = h, f \quad \text{and} \quad i \neq j, \quad (18)$$

and

$$\frac{\partial e_i}{\partial e_j} = -\frac{\frac{\partial^2 W_i}{\partial e_i \partial e_j}}{\frac{\partial^2 W_i}{\partial e_i^2}} < 0, \quad i, j = h, f \quad \text{and} \quad i \neq j. \quad (19)$$

The negative relationship between home environmental policy and foreign environmental policy stems from the nature of Cournot competition and provides support for the presence of a profit-shifting motive. We also note that, while  $\frac{\partial e_f}{\partial e_h}$  is independent of  $w$ , the absolute value of the slope of the home country's reaction function,  $\left| \frac{\partial e_h}{\partial e_f} \right|$ , falls with  $w$ ,

$$\frac{\partial \left| \frac{\partial e_h}{\partial e_f} \right|}{\partial w} < 0, \quad (20)$$

implying that the choice of the home country's emission standard becomes less sensitive to the foreign country's choice as the home country becomes more environmentally conscious (or the additional weight it places on environmental damages increases).<sup>7</sup> Simultaneously solving the two conditions in (15), we can

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<sup>7</sup> See appendix.

express the optimal emission standards in the export scenario ( $e_i^{ex}$ ) as

$$e_i^{ex} = \frac{\theta \left( \frac{\partial^2 W_i}{\partial e_i \partial e_j} - \frac{\partial^2 W_j}{\partial e_j^2} \right)}{\frac{\partial^2 W_i}{\partial e_i^2} \frac{\partial^2 W_j}{\partial e_j^2} - \left( \frac{\partial^2 W_i}{\partial e_i \partial e_j} \right)^2}, \quad i, j = h, f \quad \text{and} \quad i \neq j. \quad (21)$$

Since  $\frac{\partial^2 W_h}{\partial e_h^2} - \frac{\partial^2 W_f}{\partial e_f^2} = -w < 0$ , we have that

$$e_h^{ex} - e_f^{ex} = \frac{\theta \left( \frac{\partial^2 W_h}{\partial e_h^2} - \frac{\partial^2 W_f}{\partial e_f^2} \right)}{\frac{\partial^2 W_h}{\partial e_h^2} \frac{\partial^2 W_f}{\partial e_f^2} - \left( \frac{\partial^2 W_h}{\partial e_h \partial e_f} \right)^2} < 0, \quad (22)$$

so that standards are tighter in the home country than in the foreign country. Thus, in the absence of an FDI option, the home country can be considered as the more environmentally friendly or “green” country while the foreign country is the less environmentally friendly or the “grey” country. Accordingly, as the home country becomes more environmentally sensitive (as  $w$  increases), it chooses more stringent emission standards while the foreign country chooses less stringent standards,<sup>8</sup> that is,

$$\frac{\partial e_f^{ex}}{\partial w} > 0 > \frac{\partial e_h^{ex}}{\partial w}. \quad (23)$$

Using the optimal emission standards, we can write the profit functions of the two firms in terms of emission standards as

$$\begin{aligned} \pi_h^{ex}(e_h^{ex}, e_f^{ex}) &= \left( \frac{6\alpha + 8e_h^{ex} - 2e_f^{ex}}{15} \right)^2 - \frac{e_h^{ex^2}}{2} \\ \pi_f^{ex}(e_h^{ex}, e_f^{ex}) &= \left( \frac{6\alpha + 8e_f^{ex} - 2e_h^{ex}}{15} \right)^2 - \frac{e_f^{ex^2}}{2}. \end{aligned} \quad (24)$$

Similarly, welfare levels are

$$\begin{aligned} W_h^{ex}(e_h^{ex}, e_f^{ex}) &= \underbrace{\frac{1}{2} \left( \frac{2\alpha + e_h^{ex} + e_f^{ex}}{5} \right)^2}_{CS_h} + \underbrace{\left( \frac{6\alpha + 8e_h^{ex} - 2e_f^{ex}}{15} \right)^2 - \frac{(2+w)e_h^{ex^2}}{2}}_{PS_h - \Psi_h} \\ W_f^{ex}(e_h^{ex}, e_f^{ex}) &= \underbrace{\left( \frac{2\alpha + e_h^{ex} + e_f^{ex}}{20} \right)^2}_{CS_f} + \underbrace{\left( \frac{6\alpha + 8e_f^{ex} - 2e_h^{ex}}{15} \right)^2 - e_f^{ex^2}}_{PS_f - \Psi_f}. \end{aligned} \quad (25)$$

In the section that follows, we consider the case in which the home firm (facing a more stringent standard under export) is free to choose between export and FDI as a mode of entry into the foreign

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<sup>8</sup>See appendix for more details on emission standards under export, FDI with accomodation, and environmental policy adjustment to induce or prevent FDI.

country. For the SPNE, we then endogenize the home firm's choice over the mode of entry and the choice of environmental policy of the foreign country. We assume that the home country is passive in setting its environmental policy (setting an optimal policy as if there was a firm present) and receives no external costs or benefits from the presence or absence of its firm. The home firm then chooses whether to export or engage in FDI given the relocation cost it faces and the environmental policy it will face in the foreign country.

[Insert Figure 1a here]

## 4 Foreign Direct Investment

FDI occurs if it is profitable for the home firm to move production to the foreign country in order to take advantage of the higher emission standard in that country (or to level the playing field, as we discuss below). By relocating production to the foreign country, the home firm has to pay an exogenous plant-level fixed cost equal to  $F$ . We ignore the possibility of reciprocal FDI and focus exclusively on the FDI decision of the home firm. In addition, we allow for the possibility that the FDI-recipient or host country (i.e., the foreign country) benefits or suffers from the home firm's FDI. We denote the benefit (loss if negative) as  $B$  and, for simplicity, assume that it is exogenously given. In essence,  $B$  captures spillover effects of FDI in the host country. Although standard theory points to FDI-generated externalities which raise the productivity of host factors of production (Glass and Saggi, 1999 and 2002), the evidence about the presence of productivity spillovers is rather mixed. While a positive industry-level correlation between FDI and productivity is detected in Caves (1974), Blomström (1986), and Driffield (2000), the incidence of spillovers is found to be influenced by host industry's and host country's characteristics. At the micro-level, no evidence of higher levels of total factor productivity is found in sectors with higher foreign participation in Morocco (Haddad and Harrison, 1993), for Venezuelan manufacturing companies (Aitken and Harrison, 1999), and for low-technology Indian companies (Kathuria, 1998 and 2000).

When the home firm engages in FDI, the home and foreign firms' profits are

$$\pi_h = \sum_{j=h,f} p_j x_{hj} - \frac{1}{2} \left( \sum_{j=h,f} x_{hj} - e_f \right)^2 - F \quad (26)$$

and

$$\pi_f = \sum_{j=h,f} p_j x_{fj} - \frac{1}{2} \left( \sum_{j=h,f} x_{fj} - e_f \right)^2. \quad (27)$$

Given the foreign country's emission standard  $e_f$ , the profit-maximizing output choices must satisfy

$$\begin{aligned}\frac{\partial \pi_i}{\partial x_{ii}} &= \alpha - 3x_{ii} - x_{ji} - x_{ij} + e_f = 0 \\ \frac{\partial \pi_i}{\partial x_{ij}} &= \alpha - 3x_{ij} - x_{jj} - x_{ii} + e_f = 0, \quad i, j = h, f \quad \text{and} \quad i \neq j.\end{aligned}\tag{28}$$

Hence, in equilibrium, firm  $i$ 's output levels are

$$x_{ii} = x_{ij} = \frac{\alpha + e_f}{5}, \quad i, j = h, f \quad \text{and} \quad i \neq j.\tag{29}$$

To determine the payoffs under FDI, we need to examine several cases which differ in how the FDI-recipient country (foreign country) reacts to FDI. First, we consider the case of no reaction to FDI: the foreign country selects the emission standard above derived for the export scenario regardless of whether FDI occurs. This corresponds to a traditional pollution haven hypothesis case (i.e. firms move to countries with weaker environmental policy without regard for what happens to policy if they move). Then, we examine the case in which the foreign country endogenously determines its emission standard in response to FDI; we thus obtain conditions under which the home firm undertakes FDI and discuss the implications of FDI for the foreign country's welfare. Finally, we extend the game of Figure 1a to consider whether the foreign country has incentives to manipulate its standard to prevent (attract) FDI when FDI yields higher (lower) profits to the home firm than exporting and discuss the welfare implications of such a strategy.

#### 4.1 No response to FDI

In a typical pollution haven hypothesis case, firms facing weaker environmental standards in foreign countries shift production to those countries (in our model through FDI) without influencing local standards. With the foreign country choosing the emission standard prevailing under export, profit maximization by each firm yields identical output levels as

$$x_{ii}^{nr}(e_f^{ex}) = x_{ij}^{nr}(e_f^{ex}) = \frac{\alpha + e_f^{ex}}{5}, \quad i, j = h, f \quad \text{and} \quad i \neq j,\tag{30}$$

where the superscript  $nr$  refers to no response levels. Each firm's profit is

$$\begin{aligned}\pi_h^{nr}(e_f^{ex}) &= \frac{8\alpha(\alpha + 2e_f^{ex}) - 17e_f^{ex^2}}{50} - F \\ \pi_f^{nr}(e_f^{ex}) &= \frac{8\alpha(\alpha + 2e_f^{ex}) - 17e_f^{ex^2}}{50}\end{aligned}\tag{31}$$

and foreign welfare is

$$W_f^{nr}(e_f^{ex}) = \frac{12\alpha(\alpha + 2e_f^{ex}) - 63e_f^{ex^2}}{50} + B.\tag{32}$$

We note that FDI only occurs if the home firm's profits are greater through FDI than through export. Specifically, if the fixed cost of relocating production to the foreign country is sufficiently low, the home firm prefers FDI to export as a mode of entry, that is,

$$\pi_h^{nr}(e_f^{ex}) - \pi_h^{ex}(e_h^{ex}, e_f^{ex}) \geq 0 \quad \text{iff } F \leq F^{nr}, \quad (33)$$

where

$$F^{nr} = \frac{8\alpha(\alpha + 2e_f^{ex}) - 17e_f^{ex^2}}{50} - \left(\frac{6\alpha + 8e_h^{ex} - 2e_f^{ex}}{15}\right)^2 + \frac{e_h^{ex^2}}{2}, \quad (34)$$

with

$$\frac{\partial F^{nr}}{\partial w} > 0, \quad (35)$$

or that the critical value of  $F$  (below which the home firm engages in FDI) increases in  $w$ . In other words, as the emission standards of the two countries become more asymmetric (as  $w$  increases), the home firm has greater incentives to engage in FDI in the foreign country.

If there exists no benefit from FDI, the foreign country strictly prefers the home firm to export rather than to perform FDI. There are three distinct effects of FDI on the foreign country: (i) a decrease in the foreign firm's profits from a loss in competitive advantage; (ii) an increase in environmental damages from a rise in local production; (iii) an increase in consumer surplus from a decrease in the price. The first two effects of FDI outweigh the last effect and foreign welfare falls if there exists no external benefit from receiving FDI. Hence, we can always identify a (positive) critical benefit level, denoted by  $B^{nr}$ , above which the foreign country prefers the home firm to engage in FDI rather than export, that is,

$$W_f^{nr}(e_f^{ex}) - W_f^{ex}(e_h^{ex}, e_f^{ex}) \geq 0 \quad \text{iff } B \geq B^{nr}, \quad (36)$$

where

$$B^{nr} = \left(\frac{2\alpha + e_h^{ex} + e_f^{ex}}{20}\right)^2 + \left(\frac{6\alpha + 8e_f^{ex} - 2e_h^{ex}}{15}\right)^2 - \frac{12\alpha(\alpha + 2e_f^{ex}) - 13e_f^{ex^2}}{50}. \quad (37)$$

From an environmental perspective, whenever the home firm engages in FDI and the foreign country does not change its environmental policy, environmental damages are higher in the foreign country (and therefore worldwide) relative to the export case.<sup>9</sup>

## 4.2 Optimal Response to FDI

Next, we consider the case in which the foreign country, in response to FDI, adjusts its emission standard. If FDI occurs, the foreign country has two active producers within its borders and the home firm faces the

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<sup>9</sup>See appendix for details on critical  $F$  and  $B$  values.

same standard set by the foreign country for the foreign firm. Thus, the profit-shifting motive disappears while the environmental damage effect widens. As a result, the foreign country has an incentive to lower its emission standard when faced with FDI, so that FDI acts as a disciplining device for governments wishing to exploit environmental standards to gain competitive advantage. Stage three of the game remains the same as in the no response case, so that output levels are given by (29). The foreign country, however, faces twice the environmental damages as in the export case; accordingly, it adjusts its emission standard to satisfy

$$\frac{\partial W_f}{\partial e_f} = \frac{12\alpha - 63e_f}{25} = 0, \quad (38)$$

which yields

$$e_f^{FDI} = \frac{4\alpha}{21} \quad (39)$$

as the optimal emission standard in the foreign country under FDI. Upon comparison of the above with (21), we obtain

**Proposition 1:** *The optimum emission standard in the foreign country is always more stringent when the foreign country responds to FDI optimally relative to the export and no response cases. Furthermore, the gap between the export and FDI standards in the foreign country widens as the home country becomes more environmentally conscious:*

$$e_f^{FDI} - e_f^{ex} < 0 \quad \text{and} \quad \frac{\partial (e_f^{ex} - e_f^{FDI})}{\partial w} > 0. \quad (40)$$

Since pollution is local, the foreign country not only takes into account the environmental damages generated by its own firm but also the damages generated by the home firm. In the absence of any adjustment in the emissions standard, consumer surplus is higher while producer surplus is lower since the protection of the domestic industry afforded by a weaker emission standard is lost as the home firm enters and receives the same protection. Moreover, emissions (thus environmental damages) rise significantly. Since the foreign country's benefit from FDI is exogenous, it does not affect the emission standard. In such a case, the negative effects of FDI on producer surplus and environmental damage dominate the positive effect on consumer surplus. Thus, as we illustrate in Figure 2, the foreign country has an incentive to reduce its emission standard relative to the export case.

More interesting is the comparison of the emission standard in the foreign country (originally the *grey* country) under FDI, which both the foreign and home firms face, with the emission standard in the home country (originally the *green* country) in the export scenario, that is,

$$e_f^{FDI} - e_h^{ex} \leq 0 \quad \text{if } w \leq \bar{w}, \quad (41)$$

where  $\bar{w} = \frac{1015}{939} \approx 1.08$ . Hence, we obtain

**Proposition 2:** *When the foreign country (originally the grey country) responds optimally to the home firm's FDI, its emission standard falls below the home country's (originally the green country) standard under export if  $w$  is sufficiently low.*

The above proposition implies that, when the home firm engages in FDI and the two countries' weights on environmental damage are very different, the *grey* country (the foreign country) selects an environmental standard that is weaker than the standard of the originally *green* country (the home country) under export. However, as we also show in Figure 2, the foreign country can become "greener" than the *green* country (the home country) when the two countries are sufficiently similar in weighing environmental damages.

[Insert Figure 2 here]

At high values of  $w$ , the standard in the foreign country is much higher than that in the home country. While FDI generates additional environmental damages and takes away profit-shifting motives, thus inducing the foreign country to lower its standard, these effects are not sufficiently large to eliminate the policy gap resulting from a divergence in the two countries' environmental positions. However, when the two countries are similar (i.e.,  $w$  is sufficiently low), the two countries' emission standards are not very different in the export scenario so that the damage effect and weakened profit-shifting effect under FDI outweigh the environmental weight differential effect.

From a purely environmental perspective, the home firm's FDI results in two counteracting effects in the foreign country: (i) an *emission standard effect*, according to which, when FDI is accommodated, the foreign country's emission standard falls (even below the *green* country's standard under export when  $w < \bar{w}$ ); (ii) a *scale effect*, according to which FDI raises the production level in the foreign country relative to the export case and this, in turn, increases environmental damages for a given standard. The former effect dominates the latter and FDI leads to a cleaner environment in the foreign country (and thus worldwide) relative to the export case when the foreign country responds to the home firm's FDI by lowering its emission standard. The environmental improvement does depend on  $w$ ; specifically, as  $w$  increases, the improvement gets larger or

$$\frac{\partial \left[ \Psi_f^{ex}(e_f^{ex}) - \Psi_f^{FDI}(e_f^{FDI}) \right]}{\partial w} = e_f^{ex} \frac{\partial e_f^{ex}}{\partial w} > 0, \quad (42)$$

where

$$\Psi_f^{ex}(e_f^{ex}) - \Psi_f^{FDI}(e_f^{FDI}) = \frac{(e_f^{ex} - e_f^{FDI})(e_f^{ex} + e_f^{FDI})}{2} > 0. \quad (43)$$

Using the optimum emission standard  $e_f^{FDI}$ , we find the firms' profit levels to be

$$\begin{aligned}\pi_h^{FDI}(e_f^{FDI}) &= 23 \left( \frac{2\alpha}{21} \right)^2 - F \\ \pi_f^{FDI}(e_f^{FDI}) &= 23 \left( \frac{2\alpha}{21} \right)^2\end{aligned}\tag{44}$$

and the foreign welfare level to be

$$W_f^{FDI}(e_f^{FDI}) = \frac{2\alpha^2}{7} + B.\tag{45}$$

Again, if the fixed cost of relocating production to foreign country is sufficiently low, the home firm prefers FDI to export as a mode of entry, that is,

$$\pi_h^{FDI}(e_f^{FDI}) - \pi_h^{ex}(e_h^{ex}, e_f^{ex}) \geq 0 \quad \text{if } F \leq F^{FDI},\tag{46}$$

where

$$F^{FDI} = 23 \left( \frac{2\alpha}{21} \right)^2 - \left( \frac{6\alpha + 8e_h^{ex} - 2e_f^{ex}}{15} \right)^2 + \frac{e_h^{ex^2}}{2} \geq 0 \quad \text{if } w \geq \underline{w},\tag{47}$$

where  $\underline{w} \approx 0.43$ . We thus have

**Proposition 3:** *The incentive to perform FDI is increasing in  $w$ . For  $w < \underline{w}$ , the home firm does not engage in FDI. For  $w > \underline{w}$ , the home firm engages in FDI even if it entails facing tighter standards than under export at values of  $w$  ranging between  $\underline{w}$  and  $\bar{w}$ .*

As illustrated in Figure 3, the critical  $F$  value below which the home firm engages in FDI,  $F^{FDI}$ , is increasing in  $w$ . In other words, as the emission standards become relatively more asymmetric (as  $w$  increases), the home firm has greater incentives to perform FDI in the foreign country. Also, as  $e_f^{FDI} < e_f^{ex}$  holds,  $F^{FDI} < F^{nr}$  always obtains. For sufficiently small values of  $w$  ( $w < \underline{w}$ ), the home firm does not have any incentive to perform FDI in a country which adjusts its standard optimally and thus  $F^{FDI} < 0$  when  $w < \underline{w}$ . However, there are instances in which the home firm chooses to engage in FDI even though the foreign emission standard falls below its own standard under export (since  $\bar{w} > \underline{w}$ ). As  $w$  increases, the gap between the two countries' standards widens under export. Provided that  $w$  is not too large ( $w < \bar{w}$ ), the home firm prefers relocating to the foreign country, even if it ends up facing tighter standards, in order to *level the playing field*. Intuitively, if the home firm does not engage in FDI, its cost of abatement is higher than that of its competitor. By relocating to the foreign country, the home firm faces the same marginal abatement cost as the foreign firm so that it is no longer at a competitive disadvantage. When  $w$  is sufficiently high ( $w > \bar{w}$ ), the home firm faces a lower marginal abatement cost in the foreign country under FDI relative to export. Hence, the home firm has two reasons to engage in FDI: (i) to take advantage

of lower abatement costs and (ii) to remove the competitive advantage of the foreign firm resulting from differences in standards.

[Insert Figure 3 here]

Comparing the FDI regions of no response and optimal response in Figure 3, we can see that some FDI which would have occurred in the absence of accommodation is deterred when environmental standards are optimally adjusted (dark grey shaded area). This suggests that optimal response weakens the incentive to relocate production, thereby weakening the PHH (at least in the absence of manipulation of standards to induce FDI, as we show below).

We can easily show that, if there exists no benefit from FDI, the foreign country strictly prefers the home firm to export rather than to engage in FDI. The (positive) critical benefit level, denoted by  $B^{FDI}$ , above which the foreign country is better off under FDI relative to export satisfies

$$W_f^{FDI}(e_f^{FDI}) - W_f^{ex}(e_h^{ex}, e_f^{ex}) \geq 0 \quad \text{iff } B \geq B^{FDI}, \quad (48)$$

where

$$B^{FDI} = 8 \left( \frac{2\alpha + e_h^{ex} + e_f^{ex}}{20} \right)^2 + \left( \frac{6\alpha + 8e_f^{ex} - 2e_h^{ex}}{15} \right)^2 - e_f^{ex^2} - \frac{2\alpha^2}{7}. \quad (49)$$

Since the foreign country determines its emission standard optimally, the critical benefit level is smaller than the one obtained under no response, that is,  $B^{FDI} < B^{nr}$ , as we illustrate in Figure 4.

[Insert Figure 4 here]

There are two possible SPNE of the game described to this point, depending on the cost of relocation. If the cost of relocation  $F$  is higher than the critical fixed cost for FDI,  $F^{FDI}$  (which takes into account what the foreign country does with its standard if the firm relocates), the SPNE consists of the home firm not engaging in FDI and the foreign country setting its optimal export standard  $e_f^{ex}$ . However, if the cost of relocation is lower than the critical  $F$ , the SPNE consists of the firm engaging in FDI and the foreign country choosing the optimal standard  $e_f^{FDI}$ . These two potential outcomes are shaded in Figure 1a.

To enrich the game, we next consider the question of whether the foreign country can induce export (FDI) via preventing (attracting) FDI by adjusting its standard (to influence the critical fixed cost of the home firm above or below the actual relocation cost), and, if so, whether this can lead to higher foreign welfare.<sup>10</sup> As we show in the section that follows, these possibilities arise as SPNE only when the external

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<sup>10</sup>Industrial policy could be used here rather than environmental policy. Since the externality is environmental, it is not unreasonable to adjust environmental policy to induce or prevent FDI. Further, national treatment rules of the WTO (Article III) may prevent the use of industrial policy against foreign entrants.

benefits or costs of FDI take extreme values. In other words, the SPNE described to this point are also SPNE of the extended game unless the external benefit is below a critical threshold when  $F < F^{FDI}$  (so that SPNE entails the foreign country tightening its policy to induce export) or when the external benefit of FDI is above a different (higher) threshold when  $F > F^{FDI}$  (so the SPNE entails the foreign country weakening its standard to induce FDI).

### 4.3 Adjustment in Emission Standards (Manipulation)

In the preceding analysis, the initial fixed cost of relocation restricts the foreign country to setting an optimal response to FDI or export but the setup does not permit the country to be more proactive and strategically influence the mode of entry of the home firm. Although the foreign country sets its policy before the mode of entry decision is made, the external benefits or costs (being fixed) cannot directly influence the choice of policy and therefore cannot impact the mode of entry. As such, the game to this point best describes outcomes when there are limited costs or benefits to FDI for the foreign country. This strategic option adds a layer to the game, which is illustrated in Figure 1b. Here, the foreign country is not required to manipulate its standard but has the option to do so if the benefits or costs of FDI are such that its welfare increases.

[Insert Figure 1b here]

If the foreign country can tighten or relax its standard to eliminate or generate incentives for the home firm to engage in FDI, it can select its emission standard such that the home firm is (at most) indifferent between export and FDI. For a given  $e_f$ , the home firm's profit under FDI is

$$\pi_h^{FDI}(e_f) = \frac{8\alpha(\alpha + 2e_f) - 17e_f^2}{50} - F \quad (50)$$

while its profit under export is

$$\pi_h^{ex}(e_f) = \left( \frac{6\alpha + 8e_h(e_f) - 2e_f}{15} \right)^2 - \frac{e_h^2(e_f)}{2}. \quad (51)$$

From (15), the home country's best response to a change in the foreign emission standard under export is

$$e_h(e_f) = \zeta_1 + \zeta_2 e_f, \quad (52)$$

where

$$\zeta_1 = -\frac{\theta}{\frac{\partial^2 W_h}{\partial e_h^2}} = \frac{114\alpha}{313 + 225w} \quad \text{and} \quad \zeta_2 = -\frac{\frac{\partial^2 W_h}{\partial e_h \partial e_f}}{\frac{\partial^2 W_h}{\partial e_h^2}} = -\frac{23}{313 + 225w}. \quad (53)$$

Using the expressions in (53), we obtain the emission standard in the foreign country (denoted by  $\tilde{e}_f$ ) that makes the home firm indifferent between export and FDI, that is, such that  $\pi_h^{FDI}(e_f) = \pi_h^{ex}(e_f)$ , as

$$\begin{aligned} \tilde{e}_f = & -\frac{3\sqrt{1849\zeta_1^2 + 1024\alpha^2(1-\zeta_2)^2 - (1-\zeta_2)[50F(161+97\zeta_2) + 2752\alpha\zeta_1]}}{(1-\zeta_2)(161+97\zeta_2)} + \\ & + \frac{32\zeta_1 + 96\alpha(1-\zeta_2) + 97\zeta_1\zeta_2}{(1-\zeta_2)(161+97\zeta_2)}. \end{aligned} \quad (54)$$

Hence, the home firm strictly prefers export to FDI below  $\tilde{e}_f$  while it prefers FDI to export above  $\tilde{e}_f$ , that is,

$$\begin{aligned} \pi_h^{FDI}(e_f) & < \pi_h^{ex}(e_f) \quad \text{when } e_f < \tilde{e}_f \\ \pi_h^{FDI}(e_f) & > \pi_h^{ex}(e_f) \quad \text{when } e_f > \tilde{e}_f. \end{aligned} \quad (55)$$

Additionally,

$$\frac{\partial \tilde{e}_f}{\partial F} > 0 > \frac{\partial \tilde{e}_f}{\partial w}, \quad (56)$$

that is,  $\tilde{e}_f$  is increasing in  $F$  and decreasing in  $w$ . Intuitively, as  $w$  increases (the two countries become more asymmetric in their valuation of environmental damages), the home firm's incentive to engage in FDI increases as the gap between the emission standards of the two countries increases, so that the foreign country can induce or prevent FDI with a lower standard. To understand the intuition behind the positive effect of a change in  $F$  on the threshold standard  $\tilde{e}_f$ , we note that  $e_f^{FDI} < \tilde{e}_f < e_f^{ex}$  for combinations of  $F$  and  $w$  values at which the foreign country may opt for environmental policy manipulation to induce or prevent FDI.<sup>11</sup> If the home firm has no incentive to engage in FDI under optimum standards ( $F > F^{FDI}$ ) while the foreign country prefers FDI to export ( $B > B^{FDI}$ ), the foreign country must increase its standard above  $e_f^{FDI}$  to make FDI attractive (or, equally, to make export unattractive); hence,  $\tilde{e}_f > e_f^{FDI}$ . If the home firm has an incentive to engage in FDI under optimum standards ( $F < F^{FDI}$ ) while the foreign country prefers export to FDI ( $B < B^{FDI}$ ), the foreign country must lower its standard below  $e_f^{ex}$  to make export attractive or FDI unattractive; hence,  $\tilde{e}_f < e_f^{ex}$ . We thus have that, as  $F$  increases, the home firm's incentive to perform FDI decreases so that the foreign country has to increase its emission standard above  $e_f^{FDI}$  by more to induce FDI in the first instance (that is, when the home firm does not want to engage in FDI but the foreign country prefers FDI to export) while it has to decrease it below  $e_f^{ex}$  by less to induce export in the second instance (that is, when the home firm wants to engage in FDI but the foreign country prefers export to FDI); in both cases, the threshold standard  $\tilde{e}_f$  increases as  $F$  increases.

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<sup>11</sup>See appendix for more details on the relationships between  $e_f^{FDI}$  and  $\tilde{e}_f$  and between  $e_f^{ex}$  and  $\tilde{e}_f$ .

When the foreign country prevents FDI by lowering its standard below  $e_f^{ex}$  and the home firm decides to export, the home country adjusts its emission standard as well. Given that the emission standards of the two countries are strategic substitutes, a lower emission standard in the foreign country implies a higher emission standard in the home country, that is,

$$\tilde{e}_f < e_f^{ex} \implies \tilde{e}_h = \zeta_1 + \zeta_2 \tilde{e}_f > e_h^{ex}; \quad (57)$$

we thus have that

$$e_h^{ex} < \tilde{e}_h < \tilde{e}_f < e_f^{ex} \implies (\tilde{e}_f - \tilde{e}_h) < (e_f^{ex} - e_h^{ex}), \quad (58)$$

so that the gap in environmental policy between the two countries narrows, through a tightening of the foreign standard and a weakening of the home standard, when export is induced as opposed to being optimally chosen by the home firm.<sup>12</sup>

In the following subsection, we derive the conditions under which adjusting the emission standard to induce export or FDI is in the interest of the foreign country. To this end, we compare the foreign country's welfare levels in the FDI and export scenarios using the adjusted emission standard above given. We finally examine the environmental implications of adjusting emission standards to induce or prevent FDI from a global perspective as well as from the foreign country's perspective.

#### 4.3.1 Attracting FDI

We first consider the case in which the home firm has no incentive to engage in FDI under optimum standards ( $F > F^{FDI}$ ). In such a case, the foreign country can be better off by inducing FDI with  $\tilde{e}_f$  if the benefit from FDI is sufficiently large, that is,  $W_f^{FDI}(\tilde{e}_f) > W_f^{ex}(e_h^{ex}, e_f^{ex})$  if

$$B > \bar{B} = \left( \frac{2\alpha + e_h^{ex} + e_f^{ex}}{20} \right)^2 + \left( \frac{6\alpha + 8e_f^{ex} - 2e_h^{ex}}{15} \right)^2 - e_f^{ex^2} - \frac{3(2\alpha + 7\tilde{e}_f)(2\alpha - 3\tilde{e}_f)}{50}. \quad (59)$$

It follows immediately that the above critical benefit level ( $\bar{B}$ ) rises with  $F$  and falls with  $w$  since the foreign country has to make larger adjustments in its emission standard (this is more costly from a welfare perspective) to induce FDI when  $F$  gets larger or  $w$  gets smaller. Also, as  $W_f^{FDI}(\tilde{e}_f) \leq W_f^{FDI}(e_f^{FDI})$ , we always obtain that  $\bar{B} \geq B^{FDI}$ .

In light of the above, we have

**Proposition 4:** *Suppose that  $F > F^{FDI}$  holds. Then, the following SPNE result:*

- (i) *when  $B < \bar{B}$ , the home firm exports and the home and foreign countries choose their optimum emission standards  $e_h^{ex}$  and  $e_f^{ex}$ ;*

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<sup>12</sup>See section on emission standards in the appendix.

- (ii) when  $B > \bar{B}$ , the foreign country induces the home firm to engage in FDI by adjusting its emission standard to  $\tilde{e}_f$  where  $e_f^{FDI} < \tilde{e}_f < e_f^{ex}$ .

The first of these two SPNE corresponds to the SPNE of the previous “no manipulation game” when  $F > F^{FDI}$ : as long as the external benefits are sufficiently small, the foreign country simply accepts that the home firm wants to export and chooses the optimal policy for its own firm. The new SPNE occurs when these benefits are large, so that while the fixed cost would normally induce the home firm to export, the foreign country finds higher welfare from strategically *weakening* its policy to induce the home firm to relocate. We illustrate the equilibria for  $F = 0.01$  and  $\alpha = 1$  in Figure 5. For a given  $F$ , we use (47) to obtain the value of  $w$  ( $\hat{w}$ ) such that the home firm prefers export for  $w < \hat{w}$  and FDI for  $w > \hat{w}$ . As  $F$  increases,  $\hat{w}$  increases so that the home firm prefers export for a wider range of  $w$  values. Hence, in terms of Figure 5, the home firm prefers export for  $w < 0.7159$ . However, for  $B > \bar{B}$ , the foreign country prefers FDI and thus induces the home firm to engage in FDI by increasing its standard above  $e_f^{FDI}$ ; for  $B < \bar{B}$ , the foreign country prefers export and the optimum export emission standards ( $e_h^{ex}$  and  $e_f^{ex}$ ) prevail. Induced FDI results in a Pareto improvement over export: the home country is better off from higher producer surplus and consumer surplus and lower environmental damages; the foreign country is better off from the external benefits of FDI and higher consumer surplus that offset the additional environmental damages and reduced producer surplus.

[Insert Figure 5]

From an environmental perspective, when we compare worldwide environmental damages under export and under induced FDI, we obtain

**Proposition 5:** For a given  $F$ , there exists a  $w_l$  such that  $\Psi_f^{FDI}(\tilde{e}_f) > \sum_{i=h,f} \Psi_i^{ex}(e_h^{ex}, e_f^{ex})$  for  $w < w_l$  and  $\Psi_f^{FDI}(\tilde{e}_f) < \sum_{i=h,f} \Psi_i^{ex}(e_h^{ex}, e_f^{ex})$  for  $w > w_l$ , where  $w_l = 0$  if  $F = 0$  and  $w_l > 0$  if  $F > 0$ ; furthermore,  $w_l$  is increasing in  $F$ .

When the home firm does not have any incentive to engage in FDI but the foreign country adjusts its standard to induce FDI, the environment is dirtier under FDI relative to export when the two countries are not substantially different in their valuation of environmental damages unless the fixed cost is zero. As the two countries become more asymmetric ( $w$  increases), the foreign country can induce FDI with a smaller upward adjustment in its standard (from  $e_f^{ex}$ ) so that it becomes less likely for the environment to be dirtier under FDI. Conversely, as the cost of FDI the home firm faces increases, the foreign country

has to adjust its standard upward by a larger amount in order to induce the home firm to engage in FDI; hence, the range of  $w$  values for which the environment is dirtier under FDI widens.

In Figure 6, we plot the critical  $F$  ( $F^{FDI}$ ), as a function of  $w$ , below which the home firm prefers FDI over export and two isovalues curves. The isovalue curve labelled  $D^{FDI}$  shows the combinations of  $w$  and  $F$  such that the world's environmental damage under induced FDI is exactly the same as that under export. Above the  $D^{FDI}$  curve, damages are higher under induced FDI; below the curve, they are higher under export. For a given  $F$ , the  $F^{FDI}$  curve gives the critical  $w$  ( $\hat{w}$ ) such that the home country prefers export over FDI for  $w < \hat{w}$ . If  $B > \bar{B}$ , the foreign country induces FDI by raising its standard above  $e_f^{FDI}$  to  $\tilde{e}_f$ ; the resulting worldwide environmental quality is worse for  $w < w_l$  and better for  $w_l < w < \hat{w}$ .

[Insert Figure 6]

The positive environmental implications of inducing FDI hold true, although for a smaller range of  $w$  values, when we only consider the foreign country's pollution level. In Figure 7, we have isovalue curves for foreign pollution level differences between induced FDI and export ( $D_f^{FDI}$ ) and between FDI and induced export ( $D_f^{ex}$ ), in addition to the isovalue curves given in Figure 6 ( $D^{FDI}$  and  $D^{ex}$ ) and the threshold level of  $F$  above which the home firm prefers export ( $F^{FDI}$ ). In Figure 7, we also show the contour of the set of feasible  $F$  values for given  $w$  values ( $F \leq \bar{F}$ ) as derived in the Appendix. Hence, the pollution level in the foreign country is lower under induced FDI than under export for  $w_{fl} < w < \hat{w}$ , with  $w_l < w_{fl}$  implying that, for  $w_l < w < w_{fl}$ , environmental quality worsens in the foreign country but improves worldwide.<sup>13</sup>

[Insert Figure 7 here]

### 4.3.2 Preventing FDI

We next consider the case in which the home firm has an incentive to engage in FDI under optimum standards ( $F < F^{FDI}$ ). The foreign country can then be better off by inducing export with  $\tilde{e}$  if the benefit from FDI is sufficiently small or negative, that is,  $W_f^{ex}(\tilde{e}_h, \tilde{e}_f) > W_f^{FDI}(e_f^{FDI})$  if

$$B < \underline{B} = 8 \left( \frac{2\alpha + \tilde{e}_h + \tilde{e}_f}{20} \right)^2 + \left( \frac{6\alpha + 8\tilde{e}_f - 2\tilde{e}_h}{15} \right)^2 - \tilde{e}_f^2 - \frac{2\alpha^2}{7}. \quad (60)$$

Since the foreign country is able to induce export with a smaller adjustment in its emission standard (this is less costly from a welfare perspective) as  $F$  increases or  $w$  decreases,  $\underline{B}$  rises with  $F$  and falls with  $w$ .

Also, as  $W_f^{ex}(\tilde{e}_h, \tilde{e}_f) \leq W_f^{ex}(e_h^{ex}, e_f^{ex})$ , we always obtain that  $\underline{B} \leq B^{FDI}$ . We thus have

<sup>13</sup>For  $F = 0.02$ , the home firm may be induced to engage in FDI for  $w < \hat{w} \approx 1.09$ . If FDI is induced, the pollution level increases in the foreign country for  $w < w_{fl} \approx 1.01$  and worldwide for  $w < w_l \approx 0.81$ . Hence, environmental quality improves in the foreign country for  $1.01 < w < 1.09$  and worldwide for  $0.81 < w < 1.09$ .

**Proposition 6:** *Suppose that  $F < F^{FDI}$  holds. Then, the following SPNE obtain:*

- (i) *when  $B > \underline{B}$ , the home firm engages in FDI and the foreign country chooses its optimum emission standard  $e_f^{FDI}$ ;*
- (ii) *when  $B < \underline{B}$ , the foreign country induces the home firm to export by adjusting its emission standard to  $\tilde{e}_f$  while the home country uses  $\tilde{e}_h$  where  $e_h^{ex} < \tilde{e}_h < \tilde{e}_f < e_f^{FDI} < e_f^{ex}$ .*

The first of these two SPNE corresponds to the SPNE of the “no manipulation game” from above when  $F < F^{FDI}$ : as long as the external costs of FDI are sufficiently small, the foreign country accepts FDI and chooses the optimal policy for the two firms present. The new SPNE occurs when these costs are significant, so that while the fixed cost would normally induce the home firm to relocate, the foreign country finds higher welfare from strategically *strengthening* its policy to eliminate the incentive to move. We illustrate the above equilibria in Figure 5 as well for a given positive  $F$  and  $\alpha$ . The home firm prefers FDI for  $w > 0.7159$ . However, for  $B < \underline{B}$ , the foreign country prefers export and thus induces the home firm to export by decreasing its standard below  $e_f^{FDI}$ ; for  $B > \underline{B}$ , the foreign country prefers FDI and thus the optimum emission standard under FDI ( $e_f^{FDI}$ ) prevails. The four possible SPNE are shaded in Figure 1b; there is a unique SPNE for each pairing of  $F$  and  $B$ .

From an environmental perspective, when we compare worldwide environmental damages under FDI and induced export, we have

**Proposition 7:** *For a given  $F$ , there exists a  $w_u$  such that  $\Psi_f^{FDI}(e_f^{FDI}) < \sum_{i=h,f} \Psi_i^{ex}(\tilde{e}_h, \tilde{e}_f)$  for  $w < w_u$  and  $\Psi_f^{FDI}(e_f^{FDI}) > \sum_{i=h,f} \Psi_i^{ex}(\tilde{e}_h, \tilde{e}_f)$  for  $w > w_u$ ; further,  $w_u$  is increasing in  $F$ .*

When the home firm does have an incentive to engage in FDI but the foreign country adjusts its standard to induce export, the environment is dirtier under FDI relative to export when the two countries are substantially different in their valuation of environmental damages. As the two countries become more symmetric ( $w$  decreases), the foreign country can induce export with a smaller downward adjustment in its standard (from  $e_f^{ex}$ ) so that it becomes less likely for the environment to be dirtier under FDI. As the cost of FDI the home firm faces increases, the foreign country has to adjust its standard downward by a smaller amount in order to induce the home firm to export; hence, the range of  $w$  values for which the environment is dirtier under FDI narrows.

In Figure 6, the isovalue curve labelled  $D^{ex}$  gives the combinations of  $w$  and  $F$  such that the world’s environmental damage under FDI is exactly the same as that under induced export. Above the  $D^{ex}$  curve, damages are lower under FDI; below the curve, they are higher under induced export. For a given  $F$  (e.g.,

$F = 0.01$ ), the  $F^{FDI}$  curve gives the critical  $w$  ( $\hat{w}$ ) such that the home firm prefers FDI over export for  $w > \hat{w}$ . If  $B < \bar{B}$ , the foreign country induces export by lowering its standard below  $e_f^{ex}$  to  $\tilde{e}_f$ ; the resulting worldwide environmental quality is worse for  $\hat{w} < w < w_u$  and better for  $w > w_u$ .

As in the induced FDI case, we find that it is possible for the foreign pollution level under FDI to be lower than the pollution level under induced export. In terms of Figure 7, we have that environmental quality improves both in the foreign country and worldwide for  $\hat{w} < w < w_{fu}$  but improves only worldwide for  $w_{fu} < w < w_u$ .<sup>14</sup>

## 5 Conclusion

An important question that has largely been ignored in the literature on the relationship between FDI and environmental policy is about strategic considerations countries entertain in setting their environmental standards under the threat of increased production from FDI, particularly when pollution is local. According to the standard PHH argument, as it relates to FDI, production shifts from countries with stringent standards to countries with weaker standards. Although there are many other factors determining plant location, the idea that firms would chase lower standards is not unreasonable and could lead to a “race to the bottom” in environmental policy. Surprisingly, the empirical evidence on the PHH is limited and, while empirical reasons have been suggested why the PHH may not hold (e.g., data, measurement of environmental stringency), theoretical explanations for the possible failure of the PHH have not been thoroughly explored. In this paper, we attempt to provide one of such theoretical explanations by examining the relationship between FDI and endogenous standards, and leave the empirical investigation of the implications of FDI for environmental policy to future work. We also consider only relocation as the preferred mode of FDI entry and do not examine other methods of entry like joint ventures (see Javorcik and Saggi, 2010). Aside from considering the question of whether and when differences in environmental policies trigger firms in countries with stringent standards to move production to countries with less stringent standards, we also examine the impact that FDI has on the global pollution level as well as on the state of the environment in FDI-recipient countries.

We show that standards can become tighter in the face of FDI and, although unlikely, may even become stricter in the originally *grey* country than in the originally *green* country (this would happen in instances in which the two countries are not very different in how they value environmental damages). Thus, when

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<sup>14</sup>For  $F = 0.02$ , the home firm may be induced to engage in export for  $w > \hat{w} \approx 1.09$ . If export is induced, the pollution level increases in the foreign country for  $w > w_{fu} \approx 1.26$  and worldwide for  $w > w_u \approx 1.71$ . Hence, environmental quality improves in the foreign country for  $1.09 < w < 1.26$  and worldwide for  $1.09 < w < 1.71$ .

environmental policy is endogenous, the PHH is weakened by the fact that the tightening of standards in FDI-recipient countries creates weaker incentives for FDI. The standard in the *grey* (FDI-recipient) country is in fact always stricter under FDI, when the country responds optimally to FDI, than under export.

When the *grey* country adjusts its environmental policy in response to FDI, the differential in environmental standards between the two countries is smaller, for a given gap in environmental friendliness between the two countries, than it would be without a reaction to increased domestic production and pollution, and decreases as the two countries become more divergent. In this way, FDI acts as a disciplining device for countries considering weakening their environmental standards for competitive gain. At the same time, the strengthening of standards under FDI serves to reduce incentives for relocation of production, so that less relocation occurs due to differences in environmental standards. This amounts to a weakening of the traditional pollution haven hypothesis: firms may not choose to relocate in response to differences in environmental policy as, by so doing, they would face stricter standards in the new location.

We then derive conditions under which the foreign country has incentives to manipulate its standard to induce FDI when the home firm prefers export (when the fixed cost of FDI is above its threshold level) or to induce export when the home firm prefers FDI (when the fixed cost of FDI is below its threshold level). Whenever manipulation is optimal, the foreign standard is weaker when FDI is induced than when it is not, and stricter when export is induced than under export. The possible manipulation of environmental policy by the foreign country to induce or prevent FDI, depending on whether the benefit from FDI exceeds or falls short of its threshold level, has important implications for the overall effect of FDI on the state of the environment. In fact, while FDI always results in a cleaner environment in the foreign country (and thus worldwide) in the absence of manipulation as the *emission standard effect* (tightening of foreign standard) always dominates the *scale effect* (increase in production in the foreign country) due to the convexity of the damage function, whether FDI yields a cleaner or dirtier environment in the presence of manipulation depends on how different the two countries are in their valuation of the environment. Specifically, FDI worsens (improves) the environment when the two countries are quite similar (different) and FDI is induced or when the two countries are quite different (similar) and FDI is not induced.

That differences in environmental awareness play an important role in how FDI affects the environment stems from the fact that incentives to engage in FDI increase with the home country's environmental awareness over and above that of the foreign country; the more different the two countries are, the larger the gap in their environmental standards and the greater the benefits the home firm can derive from FDI. When FDI is induced, the foreign standard is less stringent than in the absence of manipulation but the gap

between the two standards decreases as the home firm's incentives for FDI increase (that is, as the home country becomes more environmentally conscious); hence, the more similar the two countries are, the larger the gap and the dirtier the environment. On the other hand, when FDI is not induced, the foreign standard is more stringent than under export but the gap between the foreign standard under FDI and the foreign standard under induced export decreases as the home country becomes more environmentally conscious (or the incentives for FDI increase); hence, the more different the two countries are, the smaller the gap and the dirtier the environment. Overall, whenever FDI occurs with or without inducement, pollution is likely to decrease in FDI-recipient countries and worldwide whenever there exist neither trivial nor substantial differences in environmental attitude between the FDI-recipient and the FDI-source countries. As the cost of engaging in FDI increases, pollution is less likely to decrease under FDI, particularly in less divergent countries; in other words, the more costly FDI is, the less similar the two countries have to be in their environmental awareness for pollution to decrease under FDI.

The presence of external benefits of FDI has thus additional implications for the pollution haven hypothesis: if FDI provides significant external benefits to the recipient nation, we would expect to see more PHH-induced relocation of production as countries weaken standards to attract investment (light grey area in Figure 5); if the spillover effects of FDI are small or negative, countries may tighten standards to prevent PHH-driven relocation of production (dark grey area in Figure 5). Equilibrium outcomes ultimately depend on the fixed costs of relocation and how differently countries weigh environmental damages. Nonetheless, we show that, in most cases, FDI results in a tightening of environmental policy and is likely to improve the quality of the world environment (at least among countries that are similar in production and abatement technology that account for environmental damages when setting policy).

## 6 Appendix

### 6.1 Emission standards

Using the first-order conditions for welfare maximization with respect to the standards, we can write the two countries' reaction functions as

$$e_h = \frac{114\alpha - 23e_f}{313 + 225w}$$

and

$$e_f = \frac{114\alpha - 23e_h}{313};$$

we thus have that the absolute value of the slope of the home country's reaction function is decreasing in  $w$ , that is,

$$\frac{\partial \left| \frac{\partial e_h}{\partial e_f} \right|}{\partial w} = -\frac{23(225)}{(313 + 225w)^2} < 0,$$

while the slope of the foreign country's reaction function is independent of  $w$ .

Letting  $\beta = \frac{1}{112+75w}$ ,  $\gamma = \frac{1}{698+525w}$ , and  $\delta = \frac{1}{6496+4695w}$ , we can express the export standards as

$$e_h^{ex} = 2204\alpha\delta \quad \text{and} \quad e_f^{ex} = 38(58 + 45w)\alpha\delta,$$

so that

$$e_f^{ex} - e_h^{ex} = 1710\alpha\delta w > 0,$$

and the marginal effects of  $w$  on the standards as

$$\frac{\partial e_h^{ex}}{\partial w} = -4695\delta e_h^{ex} < 0 \quad \text{and} \quad \frac{\partial e_f^{ex}}{\partial w} = 345\delta e_h^{ex} > 0.$$

The foreign standard prevailing under FDI in the absence of any response by the foreign country is the same as that under export, that is,  $e_f^{ex}$ .

With accommodation, that is, when the foreign country adjusts its standard in response to FDI,  $e_f^{FDI} = \frac{4\alpha}{21} < e_f^{ex}$ , with the difference in standards increasing in  $w$ . We in fact have that

$$e_f^{FDI} - e_f^{ex} = -10 \left( \frac{290}{3} + \frac{571}{7}w \right) \alpha\delta < 0$$

and

$$\frac{\partial (e_f^{ex} - e_f^{FDI})}{\partial w} = 760380\alpha\delta^2 > 0.$$

Furthermore,

$$e_f^{FDI} - e_h^{ex} = 20 \left( -\frac{145}{3} + \frac{313}{7}w \right) \alpha\delta$$

which is positive for  $w > \bar{w} = \frac{1015}{939}$ .

Under environmental policy adjustment by the foreign country to induce or prevent FDI, we have that

$$\tilde{e}_f = \frac{1}{23} [2(610201 + 824400w + 270000w^2)\alpha - 5(313 + 225w)M] \beta\gamma$$

and

$$\tilde{e}_h = [2(12287 + 8775w)\alpha + 5M] \beta\gamma,$$

where

$$M = \sqrt{2} \sqrt{450(13 + 16w)^2 \alpha^2 - \frac{23}{\beta\gamma} F} > 0,$$

which gives the range of feasible  $F$  values for the system to yield a real solution as

$$F < \bar{F} = \frac{450}{23} \alpha^2 (13 + 16w)^2 \beta \gamma;$$

hence, we have that

$$\tilde{e}_f - \tilde{e}_h = \frac{15}{23} [(390 + 480w) \alpha - M] \gamma > 0.$$

We can then readily see that

$$\frac{\partial \tilde{e}_f}{\partial F} = \frac{5}{23} (313 + 225w) \beta \gamma \frac{\partial \tilde{e}_f}{\partial M} \frac{\partial M}{\partial F} > 0 < \frac{\partial \tilde{e}_h}{\partial F} = 5 \beta \gamma \frac{\partial \tilde{e}_h}{\partial M} \frac{\partial M}{\partial F}$$

as  $\frac{\partial \tilde{e}_f}{\partial M} < 0 < \frac{\partial \tilde{e}_h}{\partial M}$  and  $\frac{\partial M}{\partial F} < 0$ . The effect of  $w$  on  $\tilde{e}_f$  is not as straightforward; however, noting that

$$\frac{\partial^2 \tilde{e}_f}{\partial w \partial F} = -2250 [4166 \alpha^2 (13 + 16w) + 115(173 + 160w)F] \frac{1}{M^3} < 0$$

and

$$\left. \frac{\partial \tilde{e}_f}{\partial w} \right|_{F=0} = -2850 \alpha \beta^2 < 0,$$

we can conclude that  $\frac{\partial \tilde{e}_f}{\partial w} < 0$  for  $F > 0$ .

When comparing  $\tilde{e}_f$  with  $e_f^{ex}$  and  $\tilde{e}_h$  with  $e_h^{ex}$ , we have that  $\tilde{e}_f - e_f^{ex} = \tilde{e}_h - e_h^{ex} = 0$  for  $F = F_{ind}^{ex}$ , where

$$F_{ind}^{ex} = 342 (7540 + 6957w) \alpha^2 \delta^2 w = F^{nr},$$

$\tilde{e}_f - e_f^{ex} < 0$  for  $F < F_{ind}^{ex}$  as  $\frac{\partial(\tilde{e}_f - e_f^{ex})}{\partial F} > 0$ , and  $\tilde{e}_h - e_h^{ex} > 0$  for  $F < F_{ind}^{ex}$  as  $\frac{\partial(\tilde{e}_h - e_h^{ex})}{\partial F} < 0$ . We then obtain that, for  $F < F^{FDI} < F_{ind}^{ex}$ , that is, whenever export may have to be induced as the home firm would engage in FDI,  $\tilde{e}_f - e_f^{ex} < 0$  and  $\tilde{e}_h - e_h^{ex} > 0$ . As  $e_h^{ex} < \tilde{e}_h < \tilde{e}_f < e_f^{ex}$ , the gap in standards under export is narrower when export is induced than when it is optimally chosen by the home firm, that is,  $\tilde{e}_f - \tilde{e}_h < e_f^{ex} - e_h^{ex}$  for  $F < F^{FDI}$ .

When we compare  $\tilde{e}_f$  with  $e_f^{FDI}$ , we have that  $\tilde{e}_f - e_f^{FDI} = 0$  for  $F = F_{ind}^{FDI}$ , where

$$F_{ind}^{FDI} = \frac{50}{441} \frac{(5581 + 5082w)(-7 + 6w) \alpha^2}{(313 + 225w)^2},$$

and  $\tilde{e}_f - e_f^{FDI} > 0$  for  $F > F_{ind}^{FDI}$  given that  $\frac{\partial(\tilde{e}_f - e_f^{FDI})}{\partial F} > 0$ . Upon comparison of  $F_{ind}^{FDI}$  with  $F^{FDI}$ , we obtain that

$$F^{FDI} - F_{ind}^{FDI} = \left( \frac{313003322}{3} + \frac{1397089165}{7} w + \frac{851024400}{7} w^2 + \frac{161064000}{7} w^3 \right) \left[ \frac{e_f^{ex} - e_f^{FDI}}{(313 + 225w)^2} \right] \alpha \delta > 0;$$

hence, for any  $F > F^{FDI} > F_{ind}^{FDI}$ , that is, whenever FDI may have to be induced as the home firm would not engage in FDI,  $\tilde{e}_f - e_f^{FDI} > 0$ .

## 6.2 Critical $F$ and $B$ values

Upon comparison of  $F^{FDI}$  with  $F^{nr}$ , that is, the threshold levels of  $F$  below which the home firm engages in FDI when the foreign country adjusts its standard in response to FDI and when it does not, we obtain that

$$F^{nr} - F^{FDI} = 42 \left( \frac{290}{3} + \frac{571}{7}w \right) \left( \frac{13630}{3} + \frac{21593}{7}w \right) \alpha^2 \delta^2 > 0,$$

where

$$F^{nr} = 342 (7540 + 6957w) \alpha^2 \delta^2 w > 0 \quad \text{iff } w \geq 0$$

and

$$F^{FDI} = 40 \left( -\frac{197635}{9} + \frac{651572}{21}w + \frac{2298155}{49}w^2 \right) \alpha^2 \delta^2 > 0 \quad \text{iff } w > 0.43;$$

furthermore, we know that

$$\bar{F} - F^{nr} = \frac{18}{23} (422240 + 519829w + 146175w^2)^2 \alpha^2 \beta \gamma \delta^2 > 0,$$

where  $\bar{F}$  is the largest feasible value of  $F$ , as above defined, when we consider the possibility of policy manipulation to induce or prevent FDI. We thus derive the marginal effects of  $w$  on the two critical  $F$  values as well as their difference as

$$\frac{\partial F^{nr}}{\partial w} = 18 (422240 + 474009w) \alpha \delta^2 e_h^{ex} > 0,$$

$$\frac{\partial F^{FDI}}{\partial w} = 60 (123337 + 140250w) \alpha \delta^2 e_h^{ex} > 0,$$

and

$$\frac{\partial (F^{nr} - F^{FDI})}{\partial w} = 138 (1450 + 849w) \alpha \delta^2 e_h^{ex} > 0,$$

respectively.

Similarly, upon comparison of  $B^{FDI}$  with  $B^{nr}$ , that is, the threshold levels of  $B$  above which the foreign country is better off with FDI when it adjusts its standard in response to FDI and when it does not, we have that

$$B^{nr} - B^{FDI} = \frac{2}{7} (2030 + 1713w)^2 \alpha^2 \delta^2 > 0,$$

where

$$B^{nr} = 4408 (551 + 945w + 423w^2) \alpha^2 \delta^2 > 0$$

and

$$B^{FDI} = \frac{6}{7} (1459976 + 2541560w + 1197225w^2) \alpha^2 \delta^2 > 0.$$

Hence, we can express the marginal effects of  $w$  on the two critical  $B$  values and their difference as

$$\frac{\partial B^{nr}}{\partial w} = 6 (321610 + 352947w) \alpha \delta^2 e_h^{ex} > 0,$$

$$\frac{\partial B^{FDI}}{\partial w} = 18780 (58 + 75w) \alpha \delta^2 e_h^{ex} > 0,$$

and

$$\frac{\partial (B^{nr} - B^{FDI})}{\partial w} = 414 (2030 + 1713w) \alpha \delta^2 e_h^{ex} > 0,$$

respectively.

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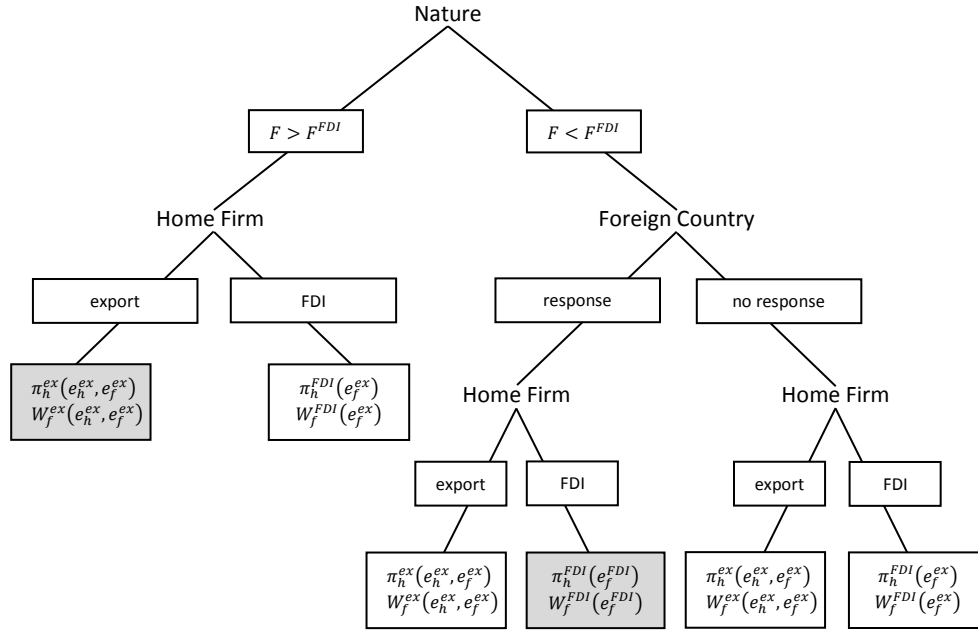


Figure 1a: Tree diagram of the game between the foreign country and the home firm under the assumption that the foreign country does not manipulate its standard to induce firms to perform FDI when the cost of relocation is high or induce firms to export when the cost of relocation is low. Shaded boxes represent SPNE depending on  $F$ .

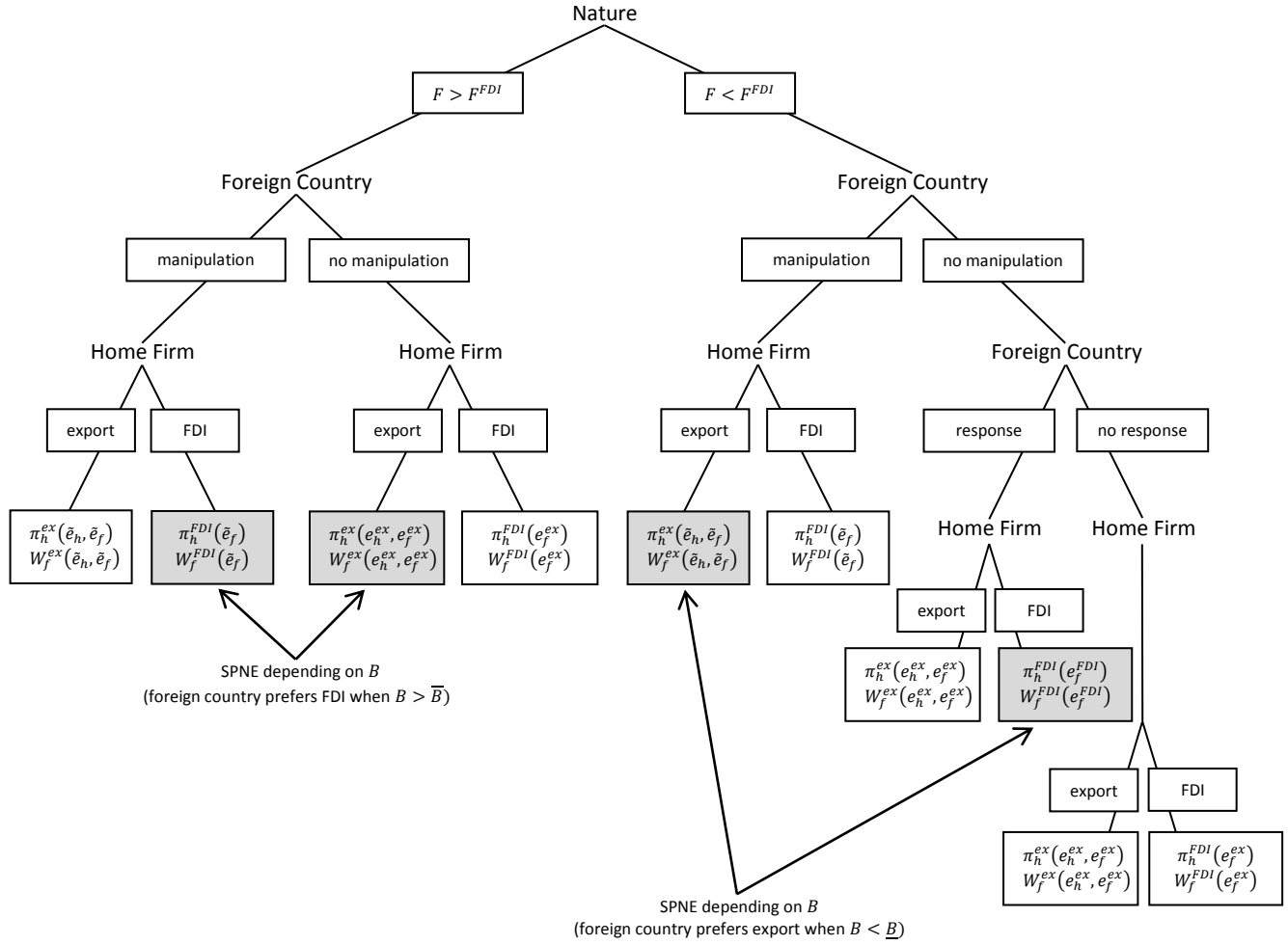


Figure 1b: Tree diagram of the game between the foreign country and the home firm when foreign country has the option to manipulate standards to induce or deter FDI. The foreign country manipulates its standard to induce FDI when  $F > F^{FDI}$  and  $B > \bar{B}$  and to induce export when  $F < F^{FDI}$  and  $B < \underline{B}$ , but does not manipulate standards when  $F > F^{FDI}$  and  $B < \bar{B}$ , or when  $F < F^{FDI}$  and  $B > \underline{B}$ .

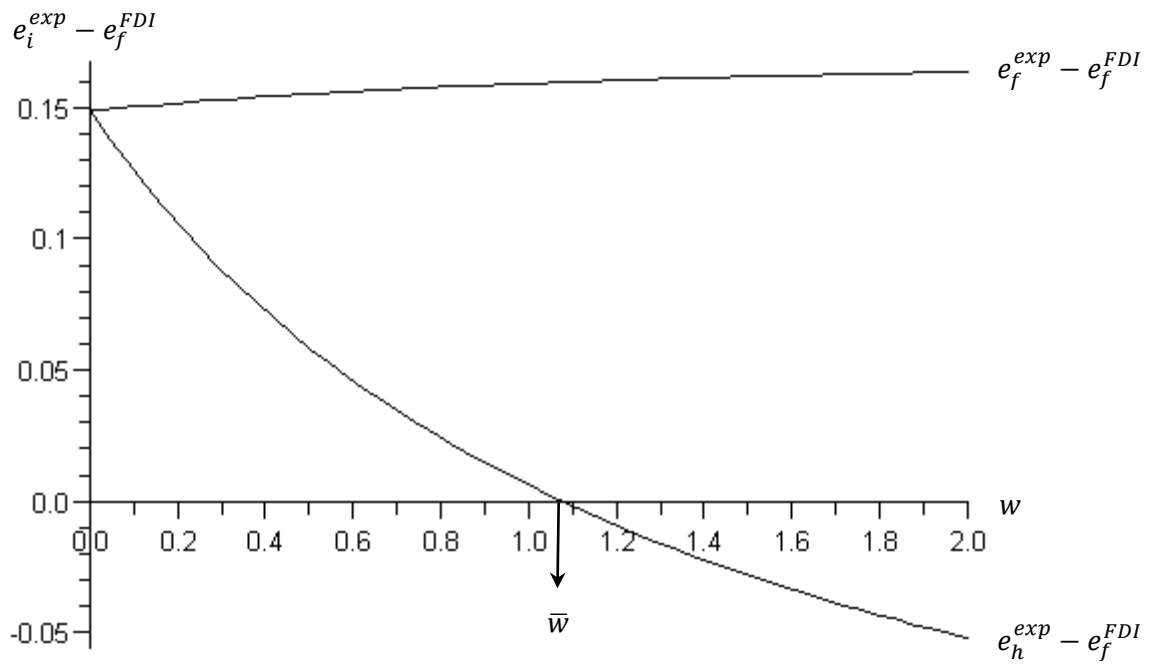


Figure 2: Emission standards under export and FDI for the home and foreign firms ( $\alpha = 1$ ;  $i = h, f$ ).

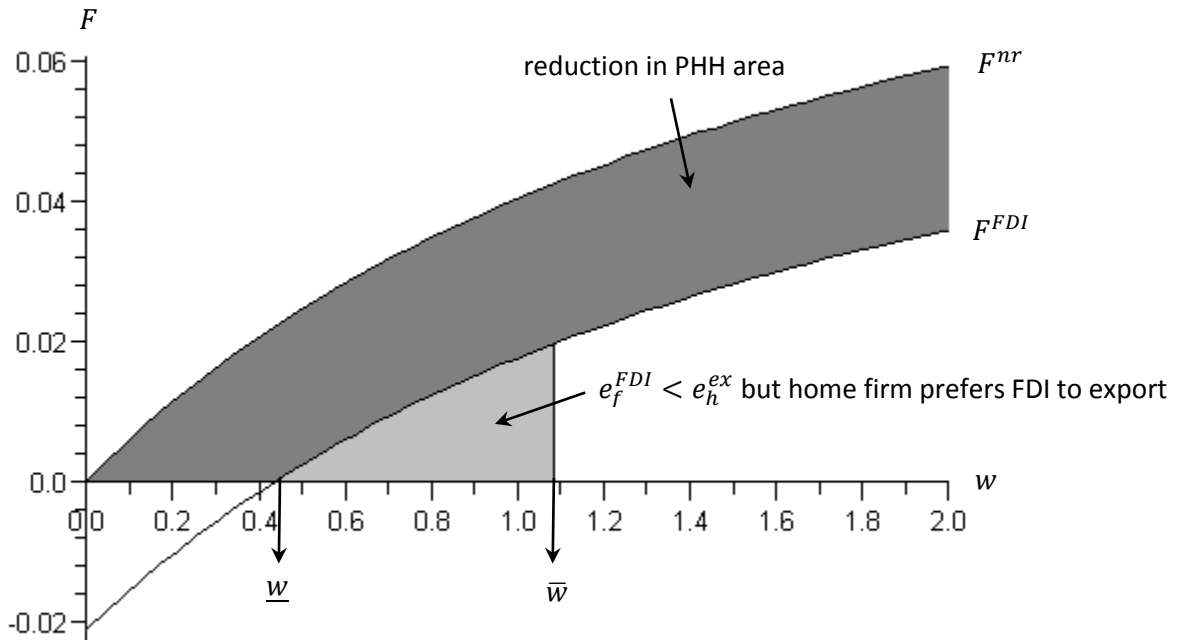


Figure 3: Critical  $F$  values and mode of entry of the home firm ( $\alpha = 1$ ).

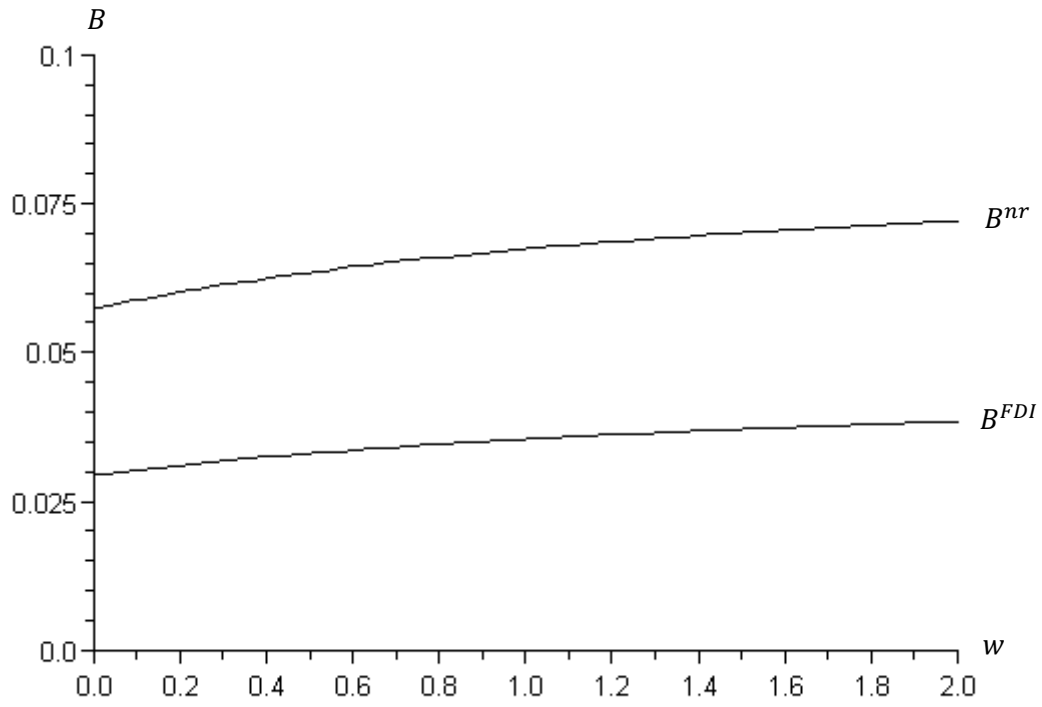


Figure 4: Critical benefit levels ( $\alpha = 1$ ).

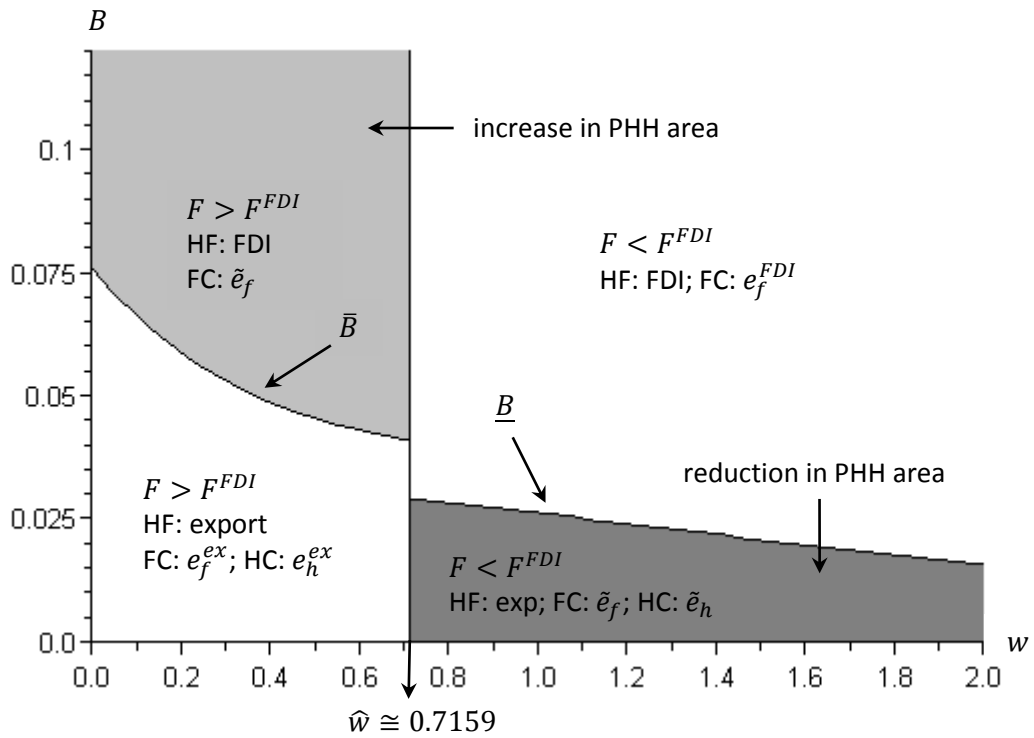


Figure 5: Possible equilibria ( $F = 0.01$ ;  $\alpha = 1$ ).

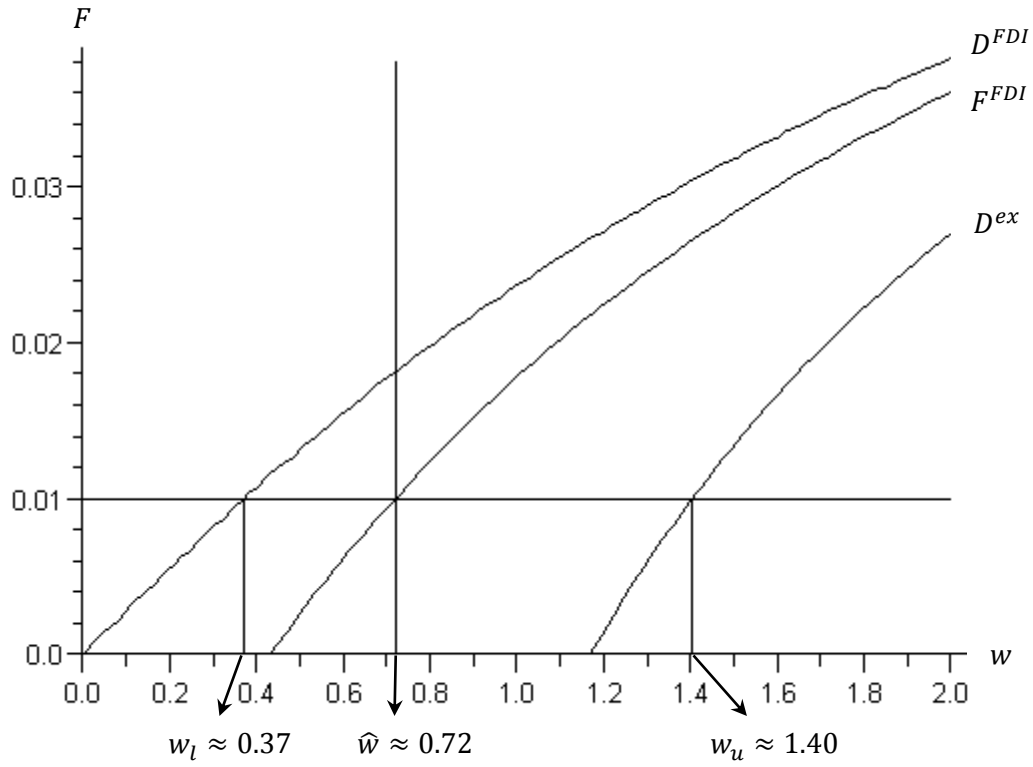


Figure 6: Critical  $w$  values for environmental considerations ( $\alpha = 1$ ).

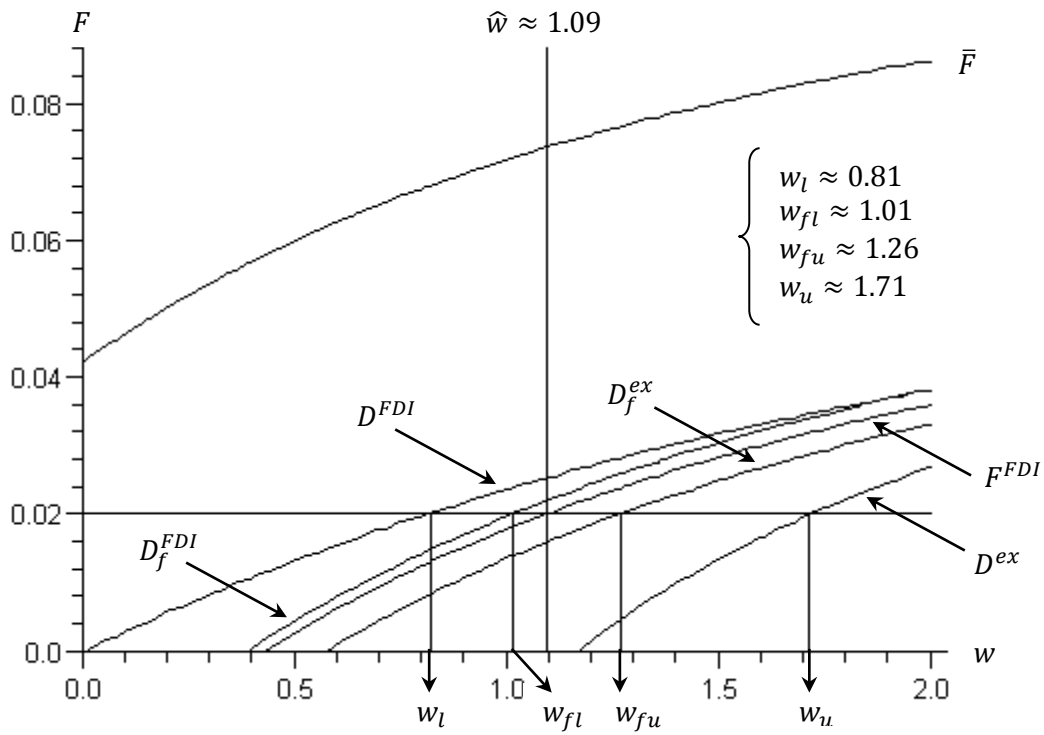


Figure 7: Critical  $w$  values for environmental considerations in the foreign country ( $\alpha = 1$ ).