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Environmental Regulation: An Incentive for FDI

by

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Abstract

Empirical evidence has so far failed to find firm support for the Pollution Haven Hypothesis that lenient environmental regulation attracts investment from polluting firms. We show that a firm may want to relocate to a country with stricter environmental regulation, when the move raises its rival's cost by sufficiently more than its own. We model a Cournot duopoly with a foreign and an incumbent domestic firm. When the foreign firm moves to the home country, the domestic government will respond by increasing the environmental tax rate. This may hurt the domestic firm more than the foreign firm thus making it profitable for the foreign firm to relocate rather than to export.

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Outline

1. *Introduction*
2. *Model*
3. *Government Policy*
 - 3.1 *Foreign Firm Exports*
 - 3.2 *Foreign firm Undertakes FDI*
4. *Export or FDI?*
5. *Equal Production Cost*
6. *Welfare*
7. *Conclusions*

Non-Technical Summary

This paper discusses the incentive effects of environmental regulation on capital mobility and market competition. We mainly address the issue of foreign direct investment and the Pollution Haven Hypothesis. Our aim is to put forward a simple theoretical model to prove that if a region/country imposes a higher environmental regulation as compared to another, then it enjoys a location choice advantage over the other region. The incentive for the foreign firm to undertake FDI in that country is based on the *raising rivals cost theory*. The raising rivals cost theory has been a widely discussed topic in IO literature and it shows the tendency of firms to raise its rivals cost in order to capture the market share enjoyed by the rival firms. In the paper the foreign firm's incentive for FDI is to raise its rivals cost by increasing the host country's environmental regulation through its investment decision.

We see that relocating in order to raise rival's cost can be profitable for the foreign firm (although it involves self-sabotage in the sense that it also increases the firm's own cost) as the firm would enjoy a higher market share as compared to when it was exporting. Thus the major finding of the paper is that the polluting capital would flow in the direction of tighter environmental regulation.

Further we see in the social welfare analysis that the welfare is lower in both the countries when the foreign firm invests in the host country and the country's governments have no way of discouraging FDI because they cannot credibly commit to an environment policy before the firm makes the location decision.

1. Introduction

As a result of globalization, the world has witnessed an unprecedented increase in Foreign Direct Investment (FDI) over the past two decades.¹ However, while stimulating economic growth and development,² FDI of polluting industries has also been considered as an important source of environmental degradation in its host region. This has fuelled a big concern of whether it is conducive and sustainable in the long run to attain economic growth and development through foreign direct investment at the expense of environmental quality. To address this concern, it is important to question whether multinationals will prefer to invest in regions with lower environmental regulation.

The Pollution Haven Hypothesis (PHH) states that polluting capital will move to countries with lenient environmental regulation. This may lead to a race to the bottom, with countries trying to undercut each other's environmental policy in order to attract polluting firms.

The empirical literature on the PHH has been inconclusive. Low and Yeates (1992), Kolstad and Xing (2001), List and Co (2000), Becker and Henderson (2000), Keller and Levinson (1999), Gray (1997) and Kahn (1997), as well as several papers analyzed by Jeppesen et al. (2001) found strong evidence in favor of the pollution haven hypothesis. List et al. (2003) found empirical evidence that air regulations in the different New York counties had a critical role in deciding the location choice of relocating industries leading to a differential industrial composition across regions. Cole and Elliott (2005) found that domestic sectoral capital intensity and pollution abatement costs have had a positive and significant effect on US FDI to Brazil and Mexico. Tobey (1992) and Eskeland and Harrison (2003), however, concluded that environmental regulation does not influence the location decision of an industry. Javorcik and Wei (2004) do not find robust support for the PHH for FDI into Eastern Europe and the former Soviet Union. Indeed, McConnell and Schwab (1990), Duffy-Deno (1992), Friedman et al. (1992) and Levinson (1996) found evidence against the PHH. In their analysis, environmental regulation had no significant, and sometimes even a positive, effect on investment. Dean et al. (2003) found that Chinese regions with high environmental stringency

¹ According to the WIR 2005, the world FDI inflow has increased since 1980 and though there was a fall from 2001 globally, it started rising again since 2004 and has risen to \$648bn.

² According to the Washington Consensus (Williamson, 1990), FDI helps in development and growth of its host economy as it brings in superior technology, capital skills, job creation, export growth and higher quality products for consumers.

attracted investment from non-Chinese sources whereas FDI from Chinese sources was deterred by high environmental regulation.

While some empirical studies find that strict environmental regulation may attract FDI, the theoretical literature has so far been built on the assumption that strict environmental regulation deters FDI.³ In this paper, we examine whether environmental regulation can act as an incentive for FDI. We consider a homogeneous Cournot duopoly with a home and a foreign firm. In stage one of the game, the foreign firm decides between exporting and relocating to the home country. In stage two, the governments set their environmental tax rates and in stage three, the firms set their respective output levels. We find that the foreign firm may prefer to relocate to the home country even when the home government sets a higher environmental tax rate than the foreign country. The incentive for the foreign firm to undertake FDI is to raise its rival's cost (Salop and Scheffman, 1983, 1987) by changing the host country's environmental regulation through its investment decision. This particular motive for FDI has not been identified in the literature before. Relocating in order to raise rival's cost can be profitable, although it involves self-sabotage (Sappington and Weisman, 2005) in the sense that it also increases the firm's own cost. We find that for FDI to be profitable, the increase in rival's cost must at least be double the increase in the firm's own cost.⁴

Sartzetakis (1997) and Puller (2006) model a firm's attempts to take advantage of environmental policy to raise its rival's cost. Sartzetakis (1997) models a tradable emission permit market in a duopoly with a leader and a follower. The leader may set a high permit price in order to raise the follower's cost. Puller (2006) shows that a firm has an incentive to innovate so that the regulator will set a stricter standard, which imposes high costs on its rivals.

The theoretical literature on the effect of environmental policy on firm location started with the seminal paper by Oates and Schwab (1988) who demonstrated that inter-jurisdictional competition for mobile capital will not lead to a race to the bottom, as long as the externality of pollution is the only distortion. A possible further distortion is when capital is not perfectly divisible as firms have a discrete location decision to make. Markusen et al. (1995), Rauscher (1995) and Hoel (1997) show that non-cooperative policy for a mobile firm does lead to

³ For example, Oates and Schwab (1988), Markusen et al. (1995), Rauscher (1995), Hoel (1997), Ulph and Valentini (2001, 2002)

⁴ Oster (1982) and Michaelis (1994) also analyze a firm's actions that raise its rival's costs more than its own costs. However, unlike the present paper, they do not model the way in which the firm's action leads to differential cost increases.

deviations from the efficient environmental policy.⁵ Depending on the circumstances, non-cooperative policy can be stricter or more lenient than the efficient environmental policy.

The above theoretical papers all assume that the government can commit to an environmental policy. Thus the government can set a very lenient environmental policy to attract the polluting firm, or a very strict policy to keep it out. However, this may not be credible. Building a plant is an irreversible decision, but announcing an environmental policy for the plant may be less so. Once the firm has built its plant, the host government can be tempted to reconsider and withdraw the lenient policy designed to attract the firm or the strict policy designed to keep it out. There is thus a problem of time inconsistency, as first analyzed in a macro-economic setting by Kydland and Prescott (1977) and Fischer (1980).

In this paper, we will assume that the government cannot commit to an environmental policy before the firm's location decision. Instead, the government sets its policy after the firm has decided where to locate. Ulph and Valentini (2001, 2002) and Petrakis and Xepapadeas (2003) compare the games where the governments set their policies before and after the firms make their location decisions. Petrakis and Xepapadeas (2003) analyze environmental taxation for a monopolist that can relocate abroad, with foreign environmental policy exogenously given. Ulph and Valentini's (2001, 2002) two-country, two-firm model differs from ours in that they assume that the firms are completely mobile at the outset of the game and all of the firm's profits accrue to the host country. We assume that all of the profits of the home (foreign) firm accrue to the home (foreign) country, and only the foreign firm can relocate. Ulph and Valentini (2001, 2002) take absolute emission limits as the instrument of environmental policy, whereas in our model we look at environmental taxation as an instrument of environment policy. Cole et al. (2006) find theoretically that a higher share of FDI in an imperfectly competitive industry should lead to more lenient environmental taxation, the more corruptible the government is. Their empirical findings confirm their hypothesis.

A De Santis and Stähler (2001) working paper looks at the case of bilateral FDI with identical firms and countries, where firms undertake FDI to avoid the transportation costs. We explicitly rule out this traditional motive by setting the foreign firm's production plus transportation costs under exporting lower than with FDI. In our paper, the motive for FDI is

⁵ Markusen et al. (1993) analyze one country's policy in a two-country, two-firm model. Kayalica and Lahiri (2005) expand the model to allow for free entry and exit, while Greaker (2003) analyzes the effect of asymmetric information about the firms' relocation costs.

that relocation leads to a higher increase in the environmental tax rate for the home firm than for the foreign firm itself. This motive is absent in De Santis and Stähler (2001), because the two firms face the same tax rates when they are located in their own countries, and therefore also the same tax increase with FDI.

The remainder of the paper is structured as follows. Section 2 introduces the model. Section 3 discusses the game under both export and FDI scenarios and Section 4 identifies the conditions under which it would be profitable for the foreign firm to do FDI. In Section 5 we look at the special case of equal production costs. In Section 6 we compare the countries' welfare under export and FDI. Section 7 provides some concluding remarks and scope for future research.

2. The Model

Consider a Cournot duopoly with one firm f initially located in the foreign country f and the other firm h located in the home country h . Firm f has the option to relocate all of its production to country h , where all the consumers live. There is a fixed cost F of relocation.⁶

The marginal cost of production of the domestic firm is constant and equal to c_h and the marginal cost of production of the foreign firm is constant and equal to c_f^x under exports (where c_f^x also includes the transportation cost) and c_f^R under FDI.⁷

We assume that:⁸

$$c_f^R \geq c_f^x \quad (1)$$

The foreign firm's marginal cost of production is higher with FDI than with exporting.⁹ As a result, it would not be profitable for the foreign firm to undertake FDI in the absence of environmental regulation. We make this assumption to ensure that environmental policy is the only reason for the firm to undertake FDI.

⁶ F captures all the start-up costs of a new plant, adjustment cost of learning to operate in a new institutional and financial environment etc.

⁷ Subscripts i , $i = f, h$, refer to the foreign and home firm or country, respectively. Superscripts s , $s = x, R$ refer to the scenario where the foreign firm is exporting and relocating, respectively.

⁸ The analysis for $c_f^R < c_f^x$ is available from the corresponding author upon request.

⁹ The marginal cost could be higher due to the higher labor or other input costs, or network cost in the market.

The firms face a linear market demand:

$$P = A - q_h^s - q_f^s$$

with $A > 0$, P the product price and q_i^s the output by firm i , $i = f, h$, in scenario s , $s = x, R$. Define for simplicity:

$$a_f^x \equiv A - c_f^x > 0 \quad a_f^R \equiv A - c_f^R > 0 \quad a_h \equiv A - c_h > 0 \quad (2)$$

Our assumption (1) can then be written as:

$$a_f^R \leq a_f^x \quad (3)$$

Pollution is a by-product of the production process. There is no technology available to reduce emissions per unit of output. In scenario s , $s = R, x$, firm i , $i = h, f$ has output q_i^s and emissions eq_i^s . Without loss of generality, we normalize the emissions-to-output ratio e to one. Total emissions E are then, for the home and foreign country, respectively:

$$\text{with export: } E_h^x = q_h^x \quad \& \quad E_f^x = q_f^x$$

$$\text{and with FDI: } E_h^R = q_h^R + q_f^R \quad \& \quad E_f^R = 0$$

Environmental damage D_i occurs only in the country i where the emissions take place, according to:

$$D_i = \lambda_i (E_i)^2$$

where λ_i is the environmental damage coefficient. The environmental damage coefficient could differ from one country to another, because one country's ecosystems could be more vulnerable to pollution than another's, or one country's citizens or government might care more about environmental damage than the other.

Marginal damage MD_i is then given by:

$$MD_i = 2\lambda_i E_i \quad (4)$$

Environmental policy in country i , $i = f, h$, under scenario s , $s = x, R$, consists of a tax t_i^s per unit of emissions. Since firms cannot reduce their emissions per unit of output, the environmental tax is effectively on output.

In addition to (1), we impose the condition:

$$t_h^R + c_f^R > t_f^x + c_f^x \quad (5)$$

i.e. full marginal costs (including production and transport costs as well as environmental taxation) are higher with FDI than with exports. Using (2), this can be rewritten as

$$t_h^R - a_f^R > t_f^x - a_f^x \quad (6)$$

We impose this condition to make sure that the foreign firm does not relocate in order to take advantage of lower costs in the home country. Using (15) and (30) where t_h^R and t_f^x are solved for, we can write condition (6) in terms of exogenous parameters as:

$$\lambda_f < \frac{3a_h(4\lambda_h^2 - 3\lambda_h - 2) - (4\lambda_h + 3)[a_f^R(3\lambda_h + 1) - a_f^x(8\lambda_h + 3)]}{2[a_f^R(4\lambda_h + 3)(2\lambda_h + 1) - a_h(3 + 6\lambda_h + 8\lambda_h^2)]} \quad (7)$$

The game between the firms and the governments consists of three stages. In the first stage, firm f decides whether to export or to undertake FDI. In stage two, the governments set the environmental tax rate that maximizes their country's welfare. In the final stage, the two firms set their output levels.

3. Government policy

In this section we analyze the second and third stage of the game. In stage two the governments decide on their environmental policies and in stage three the firms set their output levels. In subsection 3.1 (3.2), we analyze the subgame where the foreign firm has decided to export (undertake FDI).

3.1 Foreign firm exports

In this subgame, the foreign firm has decided; in stage one, to export. We start our analysis in stage three, where the two firms i , $i = f, h$ set the output levels that maximize their profits Π_i^x .

The maximization problems are, for the foreign firm:¹⁰

$$\max_{q_f^x} \Pi_f^x = (a_f^x - q_f^x - q_h^x - t_f^x)q_f^x \quad (8)$$

and for the domestic firm:

¹⁰ The second order conditions for all maximization problems in this paper are satisfied. Proofs are available from the corresponding author upon request.

$$\max_{q_h^x} \Pi_h^x = (a_h - q_h^x - q_f^x - t_h^x) q_h^x \quad (9)$$

Solving the first order conditions for the profit-maximizing output levels as a function of the tax rates yields:

$$q_h^x = \frac{2a_h - a_f^x + t_f^x - 2t_h^x}{3} \quad (10)$$

$$q_f^x = \frac{2a_f^x - a_h + t_h^x - 2t_f^x}{3} \quad (11)$$

Substituting (10) and (11) into the profit functions (8) and (9) yields:

$$\Pi_f^x = \left[\frac{2a_f^x - a_h + t_h^x - 2t_f^x}{3} \right]^2 \quad (12)$$

$$\Pi_h^x = \left[\frac{2a_h - a_f^x + t_f^x - 2t_h^x}{3} \right]^2 \quad (13)$$

In stage two, the home and foreign governments set the environmental tax rates that maximize social welfare. Social welfare W_i in country i ($i = h, f$) is the sum of firm i 's profit, consumer surplus (for the home country only) and environmental tax revenue, minus environmental damage.

The foreign government maximizes:

$$W_f^x = \Pi_f^x + t_f^x q_f^x - \lambda (q_f^x)^2 \quad (14)$$

with Π_f^x given by (12) and q_f^x given by (11). Differentiating and solving for t_f^x , we get:

$$t_f^x = \frac{(4\lambda_f - 1)(2a_f^x - a_h + t_h^x)}{4(2\lambda_f + 1)} \quad (15)$$

Similarly the host government maximizes:

$$W_h^x = \Pi_h^x + \frac{1}{2} (q_h^x + q_f^x)^2 + t_h^x q_h^x - \lambda_h (q_h^x)^2 \quad (16)$$

with Π_h^x given by (13) and q_h^x given by (10). Differentiating and solving for t_h^x , we get:

$$t_h^x = \frac{a_h(8\lambda_h - 3) - 4\lambda_h a_f^x + 4\lambda_h t_f^x}{(3 + 8\lambda_h)} \quad (17)$$

Substituting (15) into (17) and solving for t_h^x :

$$t_h^x = \frac{a_h(3\lambda_h + 4\lambda_f \lambda_h - 1 - 2\lambda_f) - 2\lambda_h a_f^x}{(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \quad (18)$$

Substituting (18) into (15) and solving for t_f^x :

$$t_f^x = \frac{(4\lambda_f - 1)(2a_f^x \lambda_h + a_f^x - a_h)}{2(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \quad (19)$$

Substituting (14) and (15) into (6) and (7), we find the equilibrium output levels as:

$$q_h^x = \frac{3a_h + 4\lambda_f a_h - a_f^x}{2(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \quad (20)$$

$$q_f^x = \frac{2\lambda_h a_f^x + a_f^x - a_h}{(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \quad (21)$$

The conditions for q_f^x and q_h^x to be positive are, respectively:

$$\lambda_h > \frac{a_h - 3a_f^x}{2a_f^x} \quad (22)$$

$$\lambda_f > \frac{a_f^x - 3a_h}{4a_h} \quad (23)$$

We wish to restrict our analysis to the case where the environmental problem is serious enough to warrant a positive environmental tax. From (18), we see that $t_h^x > 0$ if and only if:

$$\lambda_h > \frac{a_h(1 + 2\lambda_f)}{3a_h + 4a_h \lambda_f - 2a_f^x} \quad (24)$$

As for the foreign country's tax rate, the second term in brackets in the numerator on the RHS of (19) is positive by (23).

Thus $t_f^x > 0$ if and only if

$$\lambda_f > \frac{1}{4} \quad (25)$$

Using (4) and (20), the environmental tax rate (18) in the home country can be rewritten as

$$t_h^x = MD_h^x - \frac{\lambda_h a_f^x + a_h(1 + 2\lambda_f)}{1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h} \quad (26)$$

Thus the environmental tax rate is lower than the marginal damage from pollution. There are two reasons for this. First, the government wants to correct the competitive distortion existing in the market due to the presence of duopoly (the domestic correction incentive as pointed out by De Santis and Stähler, 2001). Secondly, the home government wants to shift the profit from the foreign firm to the domestic firm (the profit-shifting incentive as pointed out by Brander and Spencer, 1985).

By (4) and (21), the environmental tax rate (19) in the foreign country can be rewritten as

$$t_f^x = \left(1 - \frac{1}{4\lambda_f}\right) MD_f^x \quad (27)$$

In the foreign country as well, the environmental tax rate is below marginal damage. This is the result of the profit-shifting strategic incentive for the foreign government.

Substituting (20) and (21) into the profit functions (8) and (9), we get the profits of both firms when the foreign firm is exporting:

$$\Pi_h^x = \left[\frac{3a_h + 4\lambda_f a_h - a_f^x}{2(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \right]^2, \quad \Pi_f^x = \left[\frac{2\lambda_h a_f^x + a_f^x - a_h}{(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} \right]^2 \quad (28)$$

3.2 Foreign firm has undertaken FDI

In this subgame the foreign firm has decided, in stage one, to relocate its plant to the host country. In stage three, each firm sets the output level that maximizes its profits.

The maximization problem for firm i , $i = f, h$, is:

$$\max_{q_i^R} \Pi_i^R = (a_i - q_i^R - q_{-i}^R - t_h^R) q_i^R - F_i \quad (29)$$

with fixed cost $F_f = F$, $F_h = 0$. The first order condition gives the profit maximizing output function as follows:

$$q_f^R = \frac{2a_f^R - a_h - t_h^R}{3} \quad (30)$$

$$q_h^R = \frac{2a_h^R - a_f - t_h^R}{3} \quad (31)$$

Solving this and substituting in the profit function of the firms gives us the equilibrium level of profit as:

$$\Pi_i^R = \left[\frac{2a_i - a_{-i} - t_h^R}{3} \right]^2 - F_i \quad (32)$$

In stage two of the game, the home government sets the welfare-maximizing environmental tax rate:

$$\max_{t_h^R} W_h = \Pi_h^R + \frac{1}{2} (q_h^R + q_f^R)^2 + t_h^R (q_h^R + q_f^R) - \lambda (q_h^R + q_f^R)^2 \quad (33)$$

with Π_h^R given by (29), q_h^R by (31) and q_f^R by (30). Taking the first order condition and simplifying for t_h^R , we get:

$$t_h^R = \frac{a_h(4\lambda_h - 3) + a_f^R(3 + 4\lambda_h)}{8\lambda_h + 6} \quad (34)$$

Substituting the environmental tax rate (34) into the output levels of the firms (30) and (31) yields the profit maximizing output levels as follows:

$$q_f^R = \left[\frac{a_f^R(3 + 4\lambda_h) - a_h(4\lambda_h + 1)}{(8\lambda_h + 6)} \right] \quad , \quad q_h^R = \left[\frac{a_h(4\lambda_h + 5) - a_f^R(4\lambda_h + 3)}{(6 + 8\lambda_h)} \right] \quad (35)$$

We see that $q_f^R > 0$ always holds for $a_f^R \geq a_h$. It also holds for $a_f^R < a_h$ when:

$$\lambda_h < \frac{3a_f^R - a_h}{4(a_h - a_f^R)} \quad (36)$$

Similarly from (35), $q_h^R > 0$ always holds for $a_h \geq a_f^R$. It also holds for $a_h < a_f^R$ when:

$$\lambda_h < \frac{5a_h - 3a_f^R}{4(a_f^R - a_h)} \quad (37)$$

Using (4), (30) and (31), the environmental tax rate (34) in the home country can be rewritten as:

$$t_h^R = \frac{a_f^R - a_h}{2} + MD_h^R \quad (38)$$

As before, the domestic correction incentive leads the government to lower the tax rate below marginal damage. On the other hand, the profit-shifting incentive now calls for a higher tax than when the foreign firm is located in the foreign country. When the two firm's production costs are the same, the two incentives cancel each other out and the environmental tax is equal to the marginal environmental damage (De_Santis and Stähler, 2001). However, if the foreign firm is more productive than the home firm, the profit-shifting incentive dominates the domestic correction incentive and the tax rate is above marginal damage. The reverse occurs if the home firm is more productive.

We see that:¹¹

Lemma 1: *The home country's environmental tax rate is higher when the foreign firm relocates its plant to the home country than when it exports, i.e. $t_h^R > t_h^x$.*

The home country will set a higher tax rate under FDI, because there are now two firms on its territory rather than one. With FDI, the home and foreign firm will produce and pollute more between them than the home firm by itself under exports. Therefore, the environmental tax rate has to increase in order to protect the environment.

Finally, the two firm's profits are, substituting (34) into (32):

$$\Pi_f^R = \left[\frac{a_f^R(3 + 4\lambda_h) - a_h(4\lambda_h + 1)}{(8\lambda_h + 6)} \right]^2 - F, \quad \Pi_h^R = \left[\frac{a_h(4\lambda_h + 5) - a_f^R(4\lambda_h + 3)}{(6 + 8\lambda_h)} \right]^2 \quad (39)$$

¹¹ The proof is in the Appendix.

4. Export or FDI?

Having analyzed the second (government policy) and third (firms' output) stages of the game in the previous section, we now move to stage one where the foreign firm decides between exporting and undertaking FDI. The foreign firm prefers FDI to exports if $\Pi_f^x < \Pi_f^R$.

Comparing the foreign firm's profits (28) under export and (39) under FDI, we find:

Lemma 2: *The foreign firm prefers FDI to exporting if and only if its fixed cost of relocation F is below \hat{F} ; where*

$$\hat{F} \equiv \left[\frac{a_f^R(3+4\lambda_h) - a_h(4\lambda_h+1)}{8\lambda_h+6} \right]^2 - \left[\frac{2\lambda_h a_f^x + a_f^x - a_h}{(1+2\lambda_f+3\lambda_h+4\lambda_f\lambda_h)} \right]^2 \quad (40)$$

\hat{F} may be negative, which means that profits under exports are higher than under FDI, even without taking relocation costs into account. Thus for FDI to be profitable, \hat{F} has to be positive.

From Lemma 2, this implies:¹²

Proposition 1: *The foreign firm prefers FDI to exports for low enough relocation costs F if and only if:*

$$\frac{a_f^R(3+4\lambda_h) - a_h(4\lambda_h+1)}{8\lambda_h+6} > \frac{2\lambda_h a_f^x + a_f^x - a_h}{1+2\lambda_f+3\lambda_h+4\lambda_f\lambda_h} \quad (41)$$

and this along with $q_h^R > 0$ is satisfied if and only if $\lambda_h < \lambda_f$.

To explain the intuition behind this result, we substitute the profits under export and under FDI from (12) and (32) to rewrite condition (41) as:

$$\frac{2a_f^x - a_h + t_h^x - 2t_f^x}{3} < \frac{2a_f^R - a_h - t_h^R}{3} \quad (42)$$

Rearranging yields:

¹² The proof for $\lambda_h < \lambda_f$ is in the Appendix.

Corollary 1: *The foreign firm prefers FDI to export for low enough relocation cost F if and only if:*

$$(t_h^R + c_h) - (t_h^x + c_h) > 2[(t_h^R + c_f^R) - (t_f^x + c_f^x)] \quad (43)$$

i.e. the home firm's increase in full marginal cost is at least twice the foreign firm's increase.

We see that although FDI raises the foreign firm's own cost, it can still be worthwhile for the firm to relocate, as FDI may raise its competitor's cost by even more. As Lemma 1 has shown, the home government increases its environmental tax rate with FDI, because domestic production and pollution will be higher with two firms in the country than with one firm. It is therefore clear that FDI raises the home firm's costs. FDI also raises the foreign firm's costs by assumption (5) which we made to rule out lower costs as a motive for FDI.¹³

5. Equal production costs

In this section we examine the special case where the marginal cost of production of the foreign firm under export and under FDI equal the marginal cost of production of the domestic firm:

$$a_f^R = a_f^x = a_h = a \quad (44)$$

This enables us to have a closer look at the conditions under which the foreign firm will undertake FDI and to compare the countries' welfare under FDI and exports.

Lemma 2 now becomes:

Lemma 2: *Under condition (44), the foreign firm prefers FDI to exporting if and only if its fixed cost of relocation F is below \tilde{F} ; where*

$$\tilde{F} \equiv \left[\frac{2a}{8\lambda_h + 6} \right]^2 - \left[\frac{2a_h\lambda_h}{1 + 2\lambda_f + 3\lambda_h + 4\lambda_f\lambda_h} \right]^2 \quad (45)$$

¹³ Oster (1982) and Michaelis (1994) have results similar to our Corollary 1. However, they do not model the way in which regulation leads to a differential cost increase for the two firms.

Proposition 1 now becomes

Proposition 2: *Under condition (44), the foreign firm prefers FDI to exports for low enough relocation costs F if and only if:*

$$\lambda_f > \frac{8\lambda_h^2 + 3\lambda_h - 1}{2(2\lambda_h + 1)} \quad (46)$$

In Figure 1, this condition is satisfied above the “FDI (46)” curve. Corollary 1 becomes:

Corollary 2: *Under condition (44), the foreign firm prefers FDI to export for low enough relocation cost F if and only if:*

$$t_h^R - t_h^x > 2(t_h^R - t_f^x)$$

i.e. the tax increase for the domestic firm should be at least twice the increase for the foreign firm.

Condition (6) that ensures that costs for the foreign firm are larger in the home country now becomes $t_h^R > t_f^x$. From (7) and (44) this holds when

$$\lambda_f < \frac{7 + 16\lambda_h}{4} \quad \text{—} \quad (47)$$

In Figure 1, this condition is satisfied below the line marked “ $t_h^R > t_f^x$ (47)”.

From (20), (21) and the analysis below (36) and (37), we see that the output levels $q_f^R, q_h^R, q_h^x, q_f^x$ will always be positive with (44).

The condition for $t_f^x > 0$ is $\lambda_f > \frac{1}{4}$, as in (25). Substituting (44) into (18), we see that

$t_h^x > 0$ holds when:

$$\lambda_f > \frac{1 - \lambda_h}{2(2\lambda_h - 1)} \quad \text{—} \quad (48)$$

In Figure 1, this condition is satisfied to the right of the curve marked “ t_h^x (48)”.

The two shaded areas in Figure 1 indicate the parameter range where the foreign firm prefers to undertake FDI although it will have to pay a higher environmental tax.

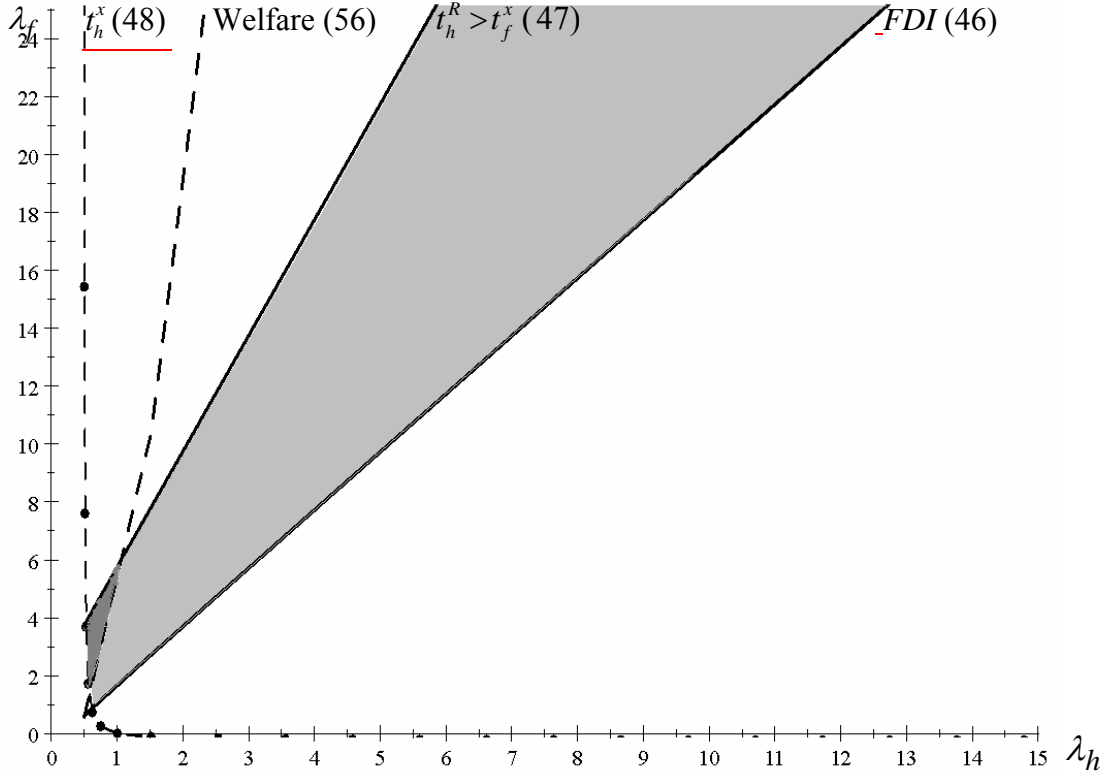


Figure 1: Environmental damage coefficients λ_f and λ_h where FDI is preferred over exports

6. Welfare

In this section we will compare the two countries' welfare with FDI and export under condition (44) that all marginal production costs are equal.

Substituting the profit of the domestic firm under export (28), the environmental tax (18), and the quantity produced by the domestic firm (20) into the welfare function of the home country (16), we find:

$$W_h^x = \frac{a^2(8\lambda_h\lambda_f^2 + 4\lambda_h^2 + 12\lambda_f\lambda_h + 4\lambda_h + 4\lambda_f^2 + 4\lambda_f + 1)}{(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f\lambda_h)^2} \quad (49)$$

Substituting the profit of the domestic firm under FDI (39), the environmental tax (34) and the quantity produced by the domestic and the foreign firm under FDI (35) into the welfare function of the home country (33), we find:

$$W_h^R = \frac{a^2}{4\lambda_h + 3} \quad \text{---} \quad (50)$$

From (49), we see that:

$$\frac{\partial W_h^x}{\partial \lambda_f} = -\frac{4a^2 \lambda_h^2 (3 + 8\lambda_h)}{(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)^3} < 0 \quad (51)$$

It then follows that the home country's welfare is higher with exports:¹⁴

$$W_h^x > \frac{a^2}{2\lambda_h + 1} > \frac{a^2}{4\lambda_h + 3} = W_h^R \quad \text{---} \quad (52)$$

The first inequality follows from (51) and letting $\lambda_f \rightarrow \infty$ in (49).

Substituting the profit of the foreign firm under export (28), the environmental tax (19) and the quantity produced by the foreign firm (21) into the welfare function of the foreign country (14), we find:

$$W_f^x = 2(1 + 2\lambda_f) \left(\frac{\lambda_h a}{1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h} \right) \quad \text{---} \quad (53)$$

Under FDI, the foreign country's welfare is equal to its firm's profits. By (39):

$$W_f^R = \left[\frac{2a}{8\lambda_h + 6} \right]^2 - F \quad (54)$$

Now define:

$$\tilde{W}_f^R \equiv W_f^R + F = \left[\frac{2a}{8\lambda_h + 6} \right]^2 \quad \text{---} \quad (55)$$

From (53) and (55) we find that $W_f^x > (<) \tilde{W}_f^R$ for $\lambda_f > (<) \tilde{\lambda}_f$, where

$$\tilde{\lambda}_f \equiv \frac{16\lambda_h^4 + 24\lambda_h^3 + 3\lambda_h^2 - 5\lambda_h - 1 + \lambda_h(3 + 4\lambda_h)\sqrt{\lambda_h(16\lambda_h^3 + 24\lambda_h^2 - 5\lambda_h - 2)}}{2(1 + 2\lambda_h)^2} \quad (56)$$

The $\tilde{\lambda}_f$ curve is drawn in Figure 1 as “Welfare (56)”. To the left of this curve, foreign welfare is higher with FDI if fixed cost F is low enough. To the right of the curve, foreign welfare is unambiguously higher with exports. As can be seen in Figure 1, as well as from (55) and (56), foreign welfare is higher with exports for all values of λ_h above 1.2.

¹⁴ In a different context, similar welfare implications are found in De Santis and Stähler (2001).

We conclude that the home country is definitely worse off and the foreign country is probably worse off when the foreign firm decides to undertake FDI rather than to export. The fall in domestic welfare is due to the reductions in consumer surplus, in the profits of the domestic firm and in environmental quality. The increase in environmental tax revenues is not enough to compensate for this loss. The foreign country's welfare falls under FDI as the increase in profit and in environmental quality is not enough to compensate for the loss of environmental tax revenue under export regime. Although the foreign firm's decision to undertake FDI (probably) makes both countries worse off, the country's governments have no way of discouraging FDI because they cannot credibly commit to policies before the firm's location decision.

7. Conclusion

It is widely feared that lenient environmental regulation attracts investment by polluting firms. In this paper we show that the opposite can hold: a foreign firm may invest in the home country although total costs (taking the costs of production, environmental taxation and transportation into account) are higher there. We have seen that the investment pays off as long as it increases the competitor (home) firm's costs by at least twice the amount of the foreign firm's own costs, a case of raising one's rival's costs (Salop and Scheffman, 1983). The home firm's costs rise because of the increase in the environmental tax rate which is necessitated by the foreign firm's relocation decision. Since we have assumed that FDI raises the foreign firm's cost of production, environmental policy is the only reason for FDI.

For simplicity we have assumed a linear demand curve and constant marginal production costs. Introducing more general functional forms would, however, not change our basic result that a firm will undertake FDI in countries with higher cost and stricter environmental regulation, as long as the difference between the rival's cost increase and its own cost increase is large enough.

We have assumed there is a single domestic firm. When there are multiple domestic firms, their costs need to rise by less than twice the foreign firm's costs in order to make FDI profitable (cf. Michaelis, 1994). On the other hand, FDI will cause a smaller increase in the environmental tax rate with multiple domestic firms.

Another significant extension of this model would be to investigate the robustness of the model, when introducing market demand in the foreign country and analyzing the export and FDI profits of both firms under environmental regulation. In this case, there could be different strategic FDI decisions made by the competing firms. It would also be interesting to analyze the model with different market structures like Bertrand, Stackleberg etc. models of competition.

Appendix

Proof of Lemma 1: From (18) and (34):

$$t_h^R - t_h^x = \frac{a_f^R(4\lambda_h + 3) - 6a_h}{8\lambda_h + 6} - \frac{a_h}{2} + \frac{a_h(4\lambda_f + 2) + 2\lambda_h a_f^x}{1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h} \quad (\text{A.1})$$

From (35), $q_f^R > 0$ if and only if:

$$a_f^R(4\lambda_h + 3) > a_h(4\lambda_h + 1) \quad (\text{A.2})$$

Applying (A.2) to the first fraction on the RHS of (A.1) and (3) to the third fraction:

$$t_h^R - t_h^x > \frac{-4a_h}{4\lambda_h + 3} + \frac{a_h(4\lambda_f + 2) + 2\lambda_h a_f^R}{1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h}$$

Applying (A.2) again yields:

$$t_h^R - t_h^x > \frac{2a_h[(2\lambda_f + 1)(4\lambda_h + 3) + \lambda_h(4\lambda_h + 1) - (1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)]}{(4\lambda_h + 3)(1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h)} > 0$$

The second inequality follows because the term between square brackets in the numerator can be rewritten as:

$$(2\lambda_f + 1)(4\lambda_h + 3) + \lambda_h(4\lambda_h + 1) - (1 + 2\lambda_f + 3\lambda_h + 4\lambda_f \lambda_h) = 2\lambda_f + (2\lambda_h - 1)^2 > 0$$

Proof of $\lambda_h < \lambda_f$ in Proposition 1: Rewriting (41), the foreign firm will find it profitable to do FDI for low enough F if

$$\frac{a_f^R}{a_h} > \frac{2a_f^x(4\lambda_h + 3)(2\lambda_h + 1) + a_h[12\lambda_h^2 - \lambda_h - 5 + 2\lambda_f(4\lambda_h + 1)(2\lambda_h + 1)]}{a_h(3 + 4\lambda_h)(1 + 3\lambda_h + 2\lambda_f(1 + 2\lambda_h))} \quad (\text{A.3})$$

From (35), we see that $q_h^R > 0$ holds if and only if:

$$\frac{a_f^R}{a_h} < \frac{4\lambda_h + 5}{4\lambda_h + 3} \quad (\text{A.4})$$

We will show that when $\lambda_f \leq \lambda_h$, inequalities (A.3) and (A.4) cannot hold simultaneously. It can be shown that the RHS of (A.3) is decreasing in λ_f . This is because the higher environmental damage, the higher will be the environmental tax rate in the foreign country and the more inclined the foreign firm will be toward FDI. Thus the lowest possible value of the

RHS in (A.3) for $\lambda_f \leq \lambda_h$ is where $\lambda_f = \lambda_h = \lambda$. A necessary condition for (A.3) to hold is then:

$$\frac{a_f^R}{a_h} > \frac{a_h(4\lambda + 5)(4\lambda^2 + \lambda - 1) + 2a_f^x(3 + 4\lambda)(2\lambda + 1)}{(3 + 4\lambda)(4\lambda + 1)(\lambda + 1)} \quad \text{--- (A.5)}$$

The RHS of (A.5) is increasing in a_f^x . The lowest possible value that the RHS can take is when a_f^x is at its minimum value, which by (3) is a_f^R . Thus, setting $a_f^R = a_f^x$, a necessary condition for (A.5) to hold is:

$$\frac{a_f^R}{a_h} > \frac{a_h(4\lambda + 5)(4\lambda^2 + \lambda - 1) + 2a_f^R(3 + 4\lambda)(2\lambda + 1)}{a_h(3 + 4\lambda)(4\lambda + 1)(\lambda + 1)}$$

Rearranging and solving for a_f^R / a_h yields:

$$\frac{a_f^R}{a_h} > \frac{4\lambda + 5}{3 + 4\lambda}$$

This is clearly irreconcilable with condition (A.4) for $q_h^R > 0$. On the other hand, if $\lambda_h < \lambda_f$, it would be possible for the foreign firm to prefer FDI and still face the domestic firm.

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