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# A Theory of Mutual Migration of Polluting Firms

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**Abstract** Suppose that governments care about their tax revenue and local firms have some say in environmental regulations. Then, the level of employment and environmental compliance may be negotiated. We find that firms located in different countries can improve their threat-point payoffs by mutual migration. This in turn affects the negotiated output/employment and environmental regulations, which causes profits to increase if the firm's threat-point payoff is higher than that of the local government. The model predicts that pollution-intensive firms or firms with highly inelastic demands are more likely to move out. Increases in the government's valuation of the environment, or in the degree of globalization also cause mutual migration of dirty firms. The effect of a government caring about consumer surplus leads to a lower pollution tax, reducing firms' incentives to move out.

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## 1. Introduction

The so-called pollution-haven hypothesis has recently generated much discussion in both political and academic circles. According to the hypothesis, pollution-intensive industries will, in response to trade liberalization, tend to move to countries that have lax environmental regulations.<sup>1</sup> Given that relocation is directly associated with investment and employment, the policy implications are substantial, since governments in different countries will have concerns in designing their environmental policies. However, while there are instances in which polluting firms have been relocated to countries with lenient environmental regulations, a majority of the empirical findings on the pollution-haven effect are negative, or at most very weak.<sup>2</sup>

More surprisingly, it has been found that polluting industries tend to migrate to the developed countries rather than the developing countries. For example, according to Repetto (1995, page 8), “to the extent that the advanced countries seem to be exporting their 'dirty' industries, they seem predominantly to be sending them to each other, not to the less developed economies.” He found that “of the total (U.S., 1992) direct foreign investment in pollution-intensive industries (petroleum & gas, chemicals, and metals), 84 percent went to other developed countries, compared to 49 percent of overseas investment in other industries.”

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<sup>1</sup> See, for instance, Antweiler, Copeland and Taylor (2001), and Markusen, Morey and Olewiler (1993).

<sup>2</sup> See, Eskeland and Harrison (2003), Keller and Levinson (1999), Co and List (2000), Walter (1982), and survey papers by Jaffe et al (1995), Levinson (1996), and Xing and Kolstad (1996). An exception is Levinson and Taylor (2003), who adopt a different approach, by using imports instead of outward FDI to measure the migration of firms. Their results indicate that the industries where abatement costs have increased most have seen the largest increases in net imports.

This paper provides an explanation for the North-North migration of polluting firms, rather than the “pollution heaven” (i.e. North-South migration) hypothesis, to shed light on the stylized empirical findings. Our approach focusing on North-North is also consistent with the fact that a majority of foreign direct investment (FDI) is *horizontal* in nature (Markusen, 1995).

In our view, the migration of polluting firms is essentially multinationals’ decision on FDI. The firm’s decision is influenced not only by the environmental regulation, but also by other factors such as the business culture, the infrastructure, the stock of skilled workers and so on in the host country. These other factors can be viewed as additional costs of FDI, which are usually higher in developing countries than in developed countries. More importantly, environmental regulations are usually considered together with other policies such as those on employment and tax revenue in the host countries.

Having noticed that large pollution-intensive firms tend to exist in oligopolistic markets (Walter, 1982), we assume that firms have some power when negotiating with a local government over employment and environmental regulations that will apply to them. Specifically, we assume a two-stage game. In the first stage, firms decide whether to migrate or not; in the second stage, if they do undertake FDI, then they engage in simultaneous bargains with the local governments to determine the environmental tax and employment.

Our setup is, of course, a very simplistic view of much more complicated issues that are often determined through negotiations/consultations between governments and industries/firms. In fact, governments often consult with a domestic industry before they actually implement their policies that apply to it. MNEs also bargain with host country

governments over many issues such as employment levels, tax breaks, or other forms of subsidies, etc. (e.g., Weiss, 1990; Hines, 1998; Ruane and Gorg, 1999). In practice, the agency that sets environmental regulations may consult with industries, representatives of residents in the affected area, and environmental groups, etc.

In this paper, we demonstrate that firms can improve their bargaining position (specifically, their threat-point payoffs) by mutual migration. This in turn affects the negotiated employment and environmental regulations, which leads to changes in firm profits and government utility. In particular, the firm's profits will increase if its threat-point payoff is higher than that of the local government. We show that pollution-intensive firms satisfy this condition and thus are more likely to move out. Intuitively, with such firms, the threat-point payoff of the government is lower due to high pollution damage, which makes it less willing to risk a breakdown in bargaining. As a consequence, the government yields a lower pollution tax to the multinational firm (i.e., with FDI) than to the national firm (i.e., without FDI).

We find that increases in the government's valuation of the environment, and in the degree of globalization (e.g., reductions in the cost of FDI) also cause polluting firms to migrate. In addition, firms with highly inelastic demand also move out because, if bargaining breaks down, firms are hurt less compared to those with elastic demand. The effect of a government caring about consumer surplus leads to a lower pollution tax, reducing firms' incentives to move out.

Thus, our model implies that polluting firms do not necessarily have to move to developing countries. If the payoffs of the firms at the threat point are not smaller than those of the governments, then the firms gain by mutual migration in developed countries.

We could incorporate a developing country into our framework, in which environmental regulations are not as strict as those in developed countries. But if the additional cost of FDI is much higher in the developing country, due to the lack of infrastructure, business culture or skilled workers, mutual migration of firms is still the equilibrium.<sup>3</sup> We also point out that, it is not necessary for the firm to possess equal bargaining power as the government does to generate our results. As long as the firm's bargaining power is positive (however small), mutual migration can arise.

In a recent article, McAusland (2002) analyzes a similar problem as ours, and shows that capital owners have an incentive to cross-haul polluting factors across jurisdictions. It arises because when capital generates pollution, those residents who are also capital owners consciously invest their pollution-generating capital in a different jurisdiction in order to reduce pollution at home. She also shows that cross-hauling induces policy makers to ratchet up environmental policies. In contrast, in the present paper, we focus on the polluting firm (not the resident), who directly exports dirty production, to avoid paying pollution taxes. In addition, tax rates are determined by negotiation between the firm and policy makers.

Section 2 develops a model of mutual migration. Section 3 looks into the asymmetric case, in which one firm migrates while the other does not. Section 4 conducts simulation exercises. Section 5 provides interpretations to the model. Section 6 investigates the case of bargaining over the tax rate only while employment decision is left to the firm. And section 7 concludes.

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<sup>3</sup> Zhang and Markusen (1999) find that much of the various added cost to investing abroad falls on fixed cost.

## 2. The Basic Setup of the Model

Suppose the world has only two countries, called the U.S. and Europe. There are also two firms: Firm A is located in the U.S. and B in Europe. The two firms produce a homogeneous product and compete in the world market. The world demand is characterized by the inverse demand function:  $p = p(x + y)$ , with  $p' < 0$ , where  $x$  and  $y$  denote the outputs in the U.S. and Europe respectively. Labor is the only variable input factor of production and is country specific. There is a one-to-one relationship between the labor input and the output by a proper choice of units. Therefore, total output is equivalent to the local employment. Production of the good generates pollution and for simplicity, we do not model pollution abatement activity and assume that one unit of output emits one unit of pollution. Hence  $x$  and  $y$  also denote the local levels of employment and pollution. There are identical technologies and zero transportation costs across countries. Since markets are not segmented, there is no intra-industry trade.

### 2.1 A Benchmark Case: No FDI

Suppose initially each firm produces only in its home country. Let the profit of each firm be

$$\pi_0 = (p - w - t)x - c(x), \quad (1a)$$

$$\pi_0^* = (p - w^* - t^*)y - c(y), \quad (1b)$$

where  $w$  and  $w^*$  are the wage rates, and  $t$  and  $t^*$  are the environmental tax rates in the U.S. and Europe respectively.  $c(\cdot)$  is a non-labor cost function, with  $c' > 0$  and  $c'' \geq 0$ . For the

rest of the analysis,  $w$  and  $w^*$  are suppressed without loss of generality since we assume them to be given. In other words, we can set  $w = w^* = 0$ .

Suppose there is also a government in each country, which cares about three things: consumer surplus, tax revenue (employment), and the cleanness of the local environment. For calculation simplicity on consumer surplus, we assume that each country always consumes half of the world output. Then the objective function of the U.S government can be written as follows.

$$g(x, t) = u\left(\frac{x+y}{2}\right) - \frac{(x+y)P}{2} + tx - \gamma d(x), \quad \gamma > 0, \quad d' > 0, \quad d'' > 0. \quad (2)$$

Where  $d(\cdot)$  is the pollution damage and  $\gamma$  represents the intensity of environmental damage that the government weighs relative to other issues (i.e., employment, etc.). The European government has a similar objective function, by switching  $x$  and  $y$ , and replacing  $t$  with  $t^*$ .

The environment tax and employment/output are determined through a cooperative Nash bargaining process between the government and the firm in each country. The bargains in the two countries are simultaneous and independent such that in the U.S. bargaining game, the European tax rate and employment are taken as given, and vice versa. This implies that the relevant demand is the residual demand in each country given the other's output.

We start with the case where neither firm attempts to move production abroad. If bargaining breaks down, the profits of the firms and the utility of the governments both go down to zero. In the spirit of Binmore et al. (1986), this outcome is the threat point for both players in each country. Therefore the Nash product in the U.S. can be written as:

$$N(x,t) = \pi g . \quad (3)$$

Observe that we have assumed equal bargaining powers for both parties. A similar expression can be established for the bargaining game in Europe.

The above game can be solved by choosing  $x$  and  $t$  to maximize  $N(x,t)$ . For simplicity, we impose symmetry across countries in the first order conditions (FOCs); that is, both firms and both governments are identical. Then it suffices to focus on one country. In the U.S. game, the equilibrium satisfies the following FOCs:

$$g\pi_x + \pi g_x = 0 , \quad (4a)$$

$$g\pi_t + \pi g_t = 0 . \quad (4b)$$

Where  $\pi_t = -x$ ,  $g_t = x$ ,  $\pi_x = p + xp' - c'(x) - t$ , and

$g_x = t - \gamma d'(x) + [u' - p - (x + y)p']/2$ . Rearranging to yield:

$$(p + xp' - c' - t) + \{(t - \gamma d') + \frac{1}{2}[u' - p - (x + y)p']\} = 0 , \quad (4a')$$

$$\pi - g = 0 . \quad (4b')$$

The first term on the LHS of (4a') is the firm's marginal profit and the second term the government's marginal utility. Thus, condition (4a') implies that the firm and the government maximize their joint objective, i.e., the sum of firm profits and government utility. Notice that the tax rate,  $t$ , is cancelled out. This is to say, the effective cost of production is just the environmental damage. The firm and the local government choose

output (employment) jointly to maximize the rent first, by setting the marginal rent to the marginal cost of environmental damage. The negotiated tax rate then redistributes the realized rent between the firm and the local government. In other words, condition (4b') gives the rule for the two players to divide the net gains from the bargaining game as measured from the threat point (zero): choosing the environment tax rate so that their net gains are equal. Note that if the bargaining powers of the two parties are different, the net gains must be divided according to their relative bargaining powers.

Totally differentiating (4a') and (4b') to yield

$$\begin{pmatrix} \pi_{xx} + g_{xx} & 0 \\ 2\pi_x & -2x \end{pmatrix} \begin{pmatrix} \partial x \\ \partial t \end{pmatrix} = \begin{pmatrix} d' \\ -d \end{pmatrix} \partial \gamma, \quad (5)$$

where  $\pi_{xx} = 2p' + xp'' - c''$ ,  $g_{xx} = -\gamma d'' + \frac{1}{2}[u''/2 - 2p' - (x+y)p'']$ , and  $\pi_{xx} + g_{xx} < 0$  to ensure stability. The comparative statics results are obtained as

$$\partial x / \partial \gamma = d' / (\pi_{xx} + g_{xx}) < 0, \quad (6a)$$

$$\partial t / \partial \gamma = \{d(\pi_{xx} + g_{xx}) + 2d_x \pi_x\} / \{2x(\pi_{xx} + g_{xx})\}. \quad (6b)$$

Expression (6a) states that an increase in the government's valuation of the environment (relative to employment, etc.) reduces the negotiated employment, because production emits pollution. The sign of (6b) is ambiguous. As long as  $\pi_x$  is not too large, (6b) becomes positively signed, which implies that an increase in the government's valuation of the environment raises the negotiated tax on pollution.

## 2.2 Mutual Migration

In this subsection, we analyze the case in which firms undertake mutual FDI. In order to produce in a foreign country, a fixed cost  $F$  must be first incurred. The government bargains separately and simultaneously with the two firms in each country. Thus, there are four separate and simultaneous bargaining games in the two countries. Let us first focus on the two bargaining games in which firm A is involved.

We also assume that firm participation in bargaining is represented by the headquarters, not branches. One can think of a situation in which each firm sends one agent to the negotiations in each country. The agents represent the total interests of the firm, not just one branch. The agents from the same firm in two different games do not communicate during bargaining, because there is not enough time for communication in a one-shot bargaining game. This setup is similar to a Cournot-Nash quantity game in which one player takes the actions of others as given when choosing its own output.

Since local governments are internationally independent, it may seem apparent that when the two firms cross-invest, they can drive down the negotiated tax rate and increase profits because they now have one more alternative--the overseas branch. But it is exactly this additional alternative that may add to the tax base of the government. Besides, as shown below, each firm's profit function simultaneously enters the Nash products in the two countries, which makes the Nash products interdependent. These issues will be clarified in this subsection.

Under mutual FDI, the threat-point payoffs for the firms and the local governments are both positive. This is so because on the one hand, if bargaining breaks down in one country, the firm can produce in the other country and import back; on the other hand, if

bargaining with firm A breaks down, the government can still obtain utility from firm B's production.

Let  $x_A$  and  $x_B$  respectively be the outputs of firms A and B in the U.S.; and  $y_B$  and  $y_A$  be the outputs of B and A in Europe. Then the world total output is  $z = x_A + x_B + y_A + y_B$ , and the inverse demand function becomes  $p(z)$ . The profits of firms A and B in the U.S. can be written respectively as

$$\pi_A = (p - t_A)x_A - c(x_A), \quad \pi_B = (p - t_B)x_B - c(x_B) - F. \quad (7a)$$

The counterparts in Europe can be written as

$$\pi_A^* = (p - t_A^*)y_A - c(y_A) - F, \quad \pi_B^* = (p - t_B^*)y_B - c(y_B). \quad (7b)$$

Note that in (7a) and (7b), only the foreign branches incur the fixed cost. The local governments' utility functions in the U.S. and Europe are respectively,

$$g = u\left(\frac{z}{2}\right) - \frac{zp}{2} + t_A x_A + t_B x_B - \gamma d(x_A + x_B), \quad (8a)$$

$$g^* = u\left(\frac{z}{2}\right) - \frac{zp}{2} + t_A^* y_A + t_B^* y_B - \gamma d(y_A + y_B). \quad (8b)$$

### 2.2.1 Firm A and the U.S. Government

Let us first investigate the two bargaining games in which firm A is involved. The Nash product between firm A and the U.S. government is:

$$K(x_A, t_A) = (\pi_A + \pi_A^* - \Pi_A^*)(g - g_B), \quad (9)$$

where  $\pi_A$  is firm A's profits from the U.S. branch,  $\pi_A^*$  is its profits from the European branch,  $\Pi_A^*$  is its threat point payoff in case bargaining breaks down in the U.S., and

$$g_B = u\left(\frac{z - x_A}{2}\right) - \frac{z - x_A}{2} p(z - x_A) + t_B x_B - \gamma d(x_B)$$

is the government's threat-point payoff, obtained only from firm B's production in the U.S.

Firm A's threat-point payoff in the U.S. bargaining game can be written as

$$\Pi_A^* = (p(x_B + y_A + y_B) - t_A^*)y_A - c(y_A) - F. \quad (10)$$

Because separate bargaining games do not break down simultaneously, (10) thus implies that if bargaining breaks down in the U.S., firm A obtains profits only from its European branch. In this case, the inverse demand is a function of firm A's European output, firm B's European and U.S. outputs.

The equilibrium to (9) satisfies the following FOCs

$$\frac{1}{2} [u' + p + (x_A + y_A - x_B - y_B)p] - c'(x_A) - \gamma d'(x_A + x_B) = 0, \quad (11a)$$

$$\pi_A + \pi_A^* - \Pi_A^* = g - g_B. \quad (11b)$$

Just like (4a'), condition (11a) states that the firm and the local government maximize their joint objective—the total rents. And (11b) indicates that firm A and the U.S. government divide the gains from the bargains equally, net of the threat-point payoffs.

### 2.2.2 Firm A and the European Government

The Nash product between firm A and the European government is:

$$K^*(y_A, t_A^*) = (\pi_A + \pi_A^* - \Pi_A)(g^* - g_B^*), \quad (12)$$

where  $g_B^* = u\left(\frac{z - y_A}{2}\right) - \frac{z - y_A}{2} p(z - y_A) + t_B^* y_B - \gamma d(y_B)$  is the European government's threat-point payoff, obtained only from firm B's production in Europe in case bargaining breaks down, and  $\Pi_A$  is firm A's threat point payoff, which can be written as

$$\Pi_A = [p(y_B + x_A + x_B) - t_A]x_A - c(x_A). \quad (13)$$

Notice that the fixed cost does not enter (13) because the U.S. is firm A's home country. Expression (13) implies that if bargaining breaks down in Europe, firm A obtains profits only from its U.S. branch. In this case, the inverse demand is a function of firm A's U.S. output, and firm B's European and U.S. outputs.

The solution to (12) satisfies the following FOCs

$$\frac{1}{2}[u' + p + (x_B + y_B - x_A - y_A)p] - c'(y_A) - \gamma d'(y_A + y_B) = 0, \quad (14a)$$

$$\pi_A + \pi_A^* - \Pi_A = g^* - g_B^*. \quad (14b)$$

Condition (14a) is similar to (11a). And condition (14b) is different from (11b) in only one place:  $\Pi_A$  does not contain the fixed cost of FDI as explained in (13).

The Nash product for the bargaining games between firm B and the two local governments can be written in a similar fashion as in (9) and (12), by just switching the subscripts A and B. And the first order conditions for taxes and employment can be

obtained analogously. Therefore, among the four players: firms A, B, the European government and the U.S. government, there are four bargaining games. By comparing all four of the Nash products, one sees that one game depends on the outcome of the others. This is because on the one hand, the firms are multinationals under mutual FDI and their participation in the bargains is represented by the total profits from both branches in the two countries; On the other hand, each local government negotiates with two firms separately and simultaneously.

Since the fixed cost of FDI is incurred before output is determined, it does not affect the level of output. Thus in the equilibrium of mutual FDI, the four branches of the two firms produce an identical level of output, i.e.,

$$x_A = x_B = y_A = y_B = \frac{z}{4}. \quad (15)$$

### 3. The Asymmetric Case: One-Way Migration

In this section, we assume that only firm A migrates to Europe, while firm B does not produce in the U.S. We compare the profits in this case with those of mutual migration and no FDI. The purpose is to demonstrate that profits are the highest under mutual FDI.

When A invests in Europe while B does not invest in the U.S., then in the U.S. the tax rate and employment are negotiated between the U.S. government and firm A, while in Europe they are determined through two separate but simultaneous bargaining games between the European government and each firm. Again bargains do not break down simultaneously. If bargaining breaks down in one game, other games are supposed to reach the equilibrium levels of employment and tax rate. Thus the conflict payoff is positive for firm A, which has branches in the U.S. and Europe. It is also positive for the European government, which negotiates with firms A and B separately. But those for firm B and the

U.S. governments are zero, since B has no subsidiary and the U.S. government bargains only with firm A's U.S. branch.

If all three bargains are successful, the total world output is  $x_A + y_A + y_B$ . Thus the inverse demand in this asymmetric case becomes  $p = p(x_A + y_A + y_B)$ , which will be used in this section unless otherwise stated.

In the U.S. game, there are only two players: the U.S. government and firm A. The Nash product can be written as

$$H(x_A, t_A) = (\pi_A + \pi_A^* - \tilde{\Pi}_A^*)g, \quad (16)$$

where  $g = u\left(\frac{x_A + y_A + y_B}{2}\right) - \frac{x_A + y_A + y_B}{2} p(x_A + y_A + y_B) + t_A x_A - \gamma d(x_A)$ , and

$\tilde{\Pi}_A^* = (p(y_A + y_B) - t_A^*)y_A - c(y_A) - F$  is firm A's threat point payoff if bargaining breaks down in the U.S. It is firm A's profits from the European branch, which also depends on firm B's production in Europe.

In Europe, there are two separate bargaining games. The Nash product for the game between firm A and the European government is:

$$H_A^*(y_A, t_A^*) = (\pi_A + \pi_A^* - \tilde{\Pi}_A)(g^* - g_B^*), \quad (17)$$

where  $g^* = u\left(\frac{x_A + y_A + y_B}{2}\right) - \frac{x_A + y_A + y_B}{2} p(x_A + y_A + y_B) + t_A^* y_A + t_B^* y_B - \gamma d(y_A + y_B)$ .

Expression  $\tilde{\Pi}_A$  is the threat-point payoff for firm A in the European bargaining game. It can be expressed as:

$$\tilde{\Pi}_A = (p(x_A + y_B) - t_A)x_A - c(x_A). \quad (18)$$

That is, if bargaining breaks down, firm A obtains profits from its production in the U.S., which also depends on firm B's output in Europe.

In (17), the threat-point payoff for the European government is:

$$g_B^*(t_B^*, y_B) = u\left(\frac{x_A + y_B}{2}\right) - \frac{x_A + y_B}{2} p(x_A + y_B) + t_B^* y_B - \gamma d(y_B). \quad (19)$$

That is, if bargaining with firm A breaks down, the European government obtains utility from the bargains with firm B.

In the second game in Europe, the local government bargains with firm B. The Nash product is:

$$H_B^*(y_B, t_B^*) = \pi_B^*(g^* - g_A^*). \quad (20)$$

Notice that the threat-point for firm B is zero because it does not invest in the U.S., while that for the European government is  $g_A^*(t_A^*, y_A) > 0$ , which can be written similarly as in (19), by replacing the subscript  $A$  with  $B$ .

After setting up the three separate and simultaneous bargaining games, we are now ready to investigate the FOCs that determine the outcomes. Treating the threat point as given, the FOCs for the U.S. game in (16) can be written as:

$$\frac{1}{2}[u' + p + (x_A + y_A - y_B)p] - c'(x_A) - \gamma d'(x_A) = 0, \quad (21a)$$

$$\pi_A + \pi_A^* - \tilde{\Pi}_A^* = g. \quad (21b)$$

The outcome of the bargaining game between the European government and firm A satisfies the following FOCs:

$$\frac{1}{2}[u' + p + (x_A + y_A - y_B)p] - c'(y_A) - \gamma d'(y_A + y_B) = 0, \quad (22a)$$

$$\pi_A + \pi_A^* - \tilde{\Pi}_A = g^* - g_B^*. \quad (22b)$$

And the outcome of the bargaining game between the European government and firm B satisfies the following FOCs:

$$\frac{1}{2}[u' + p + (y_B - x_A - y_A)p] - c'(y_B) - \gamma d'(y_A + y_B) = 0, \quad (23a)$$

$$\pi_B^* = g^* - g_A^*. \quad (23b)$$

Now let us compare the FOCs in the three bargaining games. Observe that (21a), (22a) and (23a) are similar, implying that the local government and the firm maximize their joint rents in each game. Conditions (21b), (22b) and (23b) state that the firm and the local government equally divide the net gains from bargaining in each game, through the negotiated tax rate.

#### 4. A Simulation Exercise

Having set up the three cases of no FDI, mutual FDI and one-way FDI, we are now ready to compare their profits. Before going to the economic analysis in detail, let us provide some simulation results. To simplify the exercise, we assume away the consumer

surplus in the government's objective function in the simulations. We also assume that the demand function is linear,

$$p = a - q \quad (24)$$

where  $q$  is the output in each case. The production cost function takes the following form

$$c(q) = \beta q^2, \quad \beta \geq 0. \quad (25a)$$

And the pollution damage function is quadratic:

$$d(q) = q^2. \quad (25b)$$

Let us start with a general case, in which we simulate the model using the following values for the parameters:

$$a = 100, \quad \gamma = \frac{1}{2}, \quad \beta = \frac{1}{2}. \quad (26)$$

The profits are reported in table 1.

*Table 1: Positive Production Cost, and Bargaining over both Taxes & Employment*

Firm A \ Firm B	With FDI	Without FDI
With FDI	494-F, 494-F	626-F, 408
Without FDI	408, 626-F	400, 400

According to Table 1, (i). the profit of each firm is 400 under no FDI, and  $(494-F)$  under mutual FDI. (ii). Firm A obtains  $(626-F)$  while firm B obtains 408 if firm A undertakes FDI while firm B does not; the opposite is true if the roles of A and B are reversed. Therefore, even though FDI incurs a fixed cost, when  $F$  is not too large, in equilibrium both firms choose to undertake FDI.

One might argue that the cost function in (25a) plays a major role, because the marginal cost of production is increasing in output. Increases in production plants lower the production cost, as can be seen in table 1 in the symmetric cases. However, we shall now demonstrate that the production cost is *not* important.

In order to do this, let us get rid of the variable cost factor; that is, we assume that  $\beta = 0$  in (25a) and repeat the simulations, using identical values for the other parameters as in (26). It follows that the production cost, which was assumed quadratic initially, disappears in the profit function. The simulation results are as follows.

*Table 2: Zero Production Cost, and Bargaining over both Taxes & Employment*

Firm A \ Firm B	With FDI	Without FDI
With FDI	547-F, 547-F	470-F, 469
Without FDI	469, 470-F	469, 469

In Table 2, mutual FDI still dominates no FDI, if  $F$  is not too large, even though the variable cost factor is ignored and FDI incurs a fixed cost. It is clear that firms gain by going multinational mutually. In fact, when  $F$  is sufficiently small (specifically,  $F < 1$  in table 2), then either firm would have unilateral incentives to go multinational, because the

case of no FDI is dominated by all other cases. And as long as  $F < 77$ , mutual FDI dominates any other case and emerges as the unique Nash Equilibrium.

## 5. Comparison between Mutual FDI and No FDI

We have so far established that mutual FDI emerges as the unique Nash equilibrium under reasonable values of the parameters. In order to gain clear economic understanding, in this section, we again disregard the variable cost factor, by assuming that  $\beta = 0$  in (25a). This considerably simplifies our analysis and yet preserves the essential elements of the model. We then compare the profits, employment and taxes under mutual FDI and no FDI. Subscripts  $_H$  and  $_O$  will be used to denote “mutual FDI” and “no FDI”.

First, we check the FOCs under no FDI and mutual FDI. Under the assumption that the production cost is zero, conditions (4a') and (11a) are identical. The determining factor is the pollution damage function  $d(x)$ , which results in

$$x_A + x_B = x, \quad y_A + y_B = y. \quad (27)$$

Condition (27) arises due to constant returns to scale in production, which implies that there is no difference between locating in the two countries to the firms. However, pollution damage depends on the total production in each country. Thus symmetry ensures that total pollution (production) is identical in the two countries.

Next, we investigate the tax rate. Expanding (11b) and invoking (15) and (27) yields the negotiated tax rate for the home firm as a function of employment under mutual FDI:

$$t_H = \{px + \gamma d(x) - (\Pi_A^* - g_B + F) - [u(\frac{z}{2}) - \frac{zp}{2}]\} / (2x). \quad (28a)$$

Note that as shown in (11a) and (14a), output is not affected by  $F$ ,  $\Pi_A^*$ , and  $g_B$ . The tax rate for the foreign firm,  $t_{II}^*$ , can be obtained from (14b) in a similar fashion. However, since  $\Pi_A^*$  has a negative term  $(-F)$  which  $\Pi_A$  does not have,  $t_{II}^*$  is lower than  $t_{II}$ . That is, the government charges a lower tax to the foreign firm. From (28a), it is also clear that a government caring about consumer surplus would charge a lower pollution tax, so that output and consumer surplus can be higher.

Differentiating (28a) yields the following results:

**Proposition 1:** Under mutual FDI, (i).  $\partial t_{II} / \partial F < 0$ ; (ii).  $\partial t_{II} / \partial \Pi_A^* < 0$ ; (iii).  $\partial t_{II} / \partial g_B > 0$ .

Part (i) states that an increase in the fixed cost of FDI reduces the negotiated tax rate. This arises because if the fixed cost increases, firm profits decrease. In order to maintain (11b), rents must be redistributed to the firm through a reduction in the negotiated tax rate. Part (ii) implies that an increase in the firm's payoff at the threat point reduces the tax rate, and part (iii) implies that an increase in the local government's payoff at the threat point raises the negotiated tax rate. The economic intuition for (ii) and (iii) is as follows: Under mutual FDI, two types of play-off effects exist, if bargaining breaks down in one game. On the one hand, the firm can 'play off' the government by undertaking FDI, while on the other hand the government can 'play off' the firm by negotiating with another firm.

Expanding (4b') yields

$$t_0 = \{px + \gamma d(x) - [u(x) - xp]\} / (2x), \quad (28b)$$

which is combined with (27) and (28a) to obtain that under symmetry,

$$t_{II} - t_0 = -\frac{\Pi_A^* - g_B + F}{2x}. \quad (29)$$

Expression (29) states that the differential in the negotiated tax rate depends on the magnitudes of the two threat-point payoffs, given a fixed cost. The threat-point payoff of the firm reduces the tax rate, while that of the government raises it. Using Proposition 1, conditions (27) and (29) can be summarized in the following proposition:

**Proposition 2:** *Under mutual FDI, environmental damage (employment) remains the same as in the case of no FDI. The negotiated tax rate is lower (respectively higher) than in the case of no FDI if the threat-point payoff of the firm is higher (respectively lower) than that of the local government, net of the fixed cost.*

The changes in firm profits can be calculated as follows. Substituting  $t_{II}$ ,  $t_{II}^*$  and  $t_0$  into the profit functions with and without mutual FDI, we obtain respectively

$$\pi_{II} = \frac{px - \gamma d(x) - F}{2} + \frac{(\Pi_A^* - g_B) + (\Pi_A - g_B^*)}{4} + \frac{u(\frac{z}{2}) - \frac{zp}{2}}{2}, \quad (30a)$$

$$\pi_0 = \frac{px - \gamma d(x)}{2} + \frac{u(x) - px}{2}. \quad (30b)$$

Because output remains identical with or without mutual FDI, we thus have

$$\pi_{II} - \pi_0 = \frac{(\Pi_A^* - g_B) + (\Pi_A - g_B^*) - 2F}{4}. \quad (31)$$

That is, the changes in profits depend on the threat-point payoffs of the firms and the governments. By proposition 1, if the tax rate goes up (down) under FDI, then firm profits go down (up).

Invoking proposition 2, we can establish

**Proposition 3:** (i). *Mutual FDI dominates the case of no FDI if  $\Pi_A^* - g_B - F > 0$  ; (ii). Pollution-intensive firms, and firms with highly inelastic demands are more likely to migrate to other countries.*

**Proof:** (i). Under symmetry, the profit differential between mutual FDI and no FDI in condition (31) can be rewritten as:

$$\pi_{II} - \pi_0 = \frac{\Pi_A^* - g_B - F}{2}, \quad (31')$$

where  $\Pi_A^*$  is firm A's payoff at the threat point if bargaining in the U.S. breaks down, and  $g_B$  is the U.S. local government payoff at the threat point if bargaining with firm A breaks down. Expression (31') states that profits are higher under mutual FDI than under no FDI if the firm's threat-point payoff is higher than that of the local government, net of the fixed costs.

(ii). Invoking symmetry, expression (31') can be expanded as

$$2(\pi_{II} - \pi_0) = \{p(z - x_A) - t\}x + \gamma d(x_B) - F - \left\{u\left(\frac{z - x_A}{2}\right) - \frac{(z - x_A)p(z - x_A)}{2}\right\}. \quad (31'')$$

In (31''), the inverse demand function and the environmental damage function enter positively. QED

Part (i) of Proposition 3 implies that if the firms' threat-point payoffs are higher than the governments', net of the fixed costs, then in the first stage, firms choose to mutually migrate. Part (ii) arises because of a *demand effect* and a *damage effect*. The demand effect is as follows: with highly inelastic demands, the firm can charge high prices, and the loss from a break down in bargaining is smaller than if demand is elastic. The damage effect says that with pollution-intensive firms, the government's threat point payoff is reduced by the environmental damage and the government becomes worse off relative to the firm by a breakdown in bargaining. The demand effect raises the threat-point payoff of the firm, and the damage effect reduces that of the government, both working to the benefit of the multinational firm. As a consequence, the government yields more to the multinational firm than to the national firm in terms of the negotiated pollution tax.

Furthermore, we can also establish:

**Proposition 4:** (i). *Ceteris paribus, an increase in the government's valuation of the environment, or in the degree of globalization (i.e., reductions in the fixed cost of FDI) increases the likelihood for firms to mutually migrate;* (ii). *The government's consideration of consumer surplus in its objective has a negative effect on the firm's decision to migrate.*

**Proof:** (i). Partially differentiating (31') to obtain,

$$\frac{\partial(\pi_H - \pi_0)}{\partial\gamma} = \frac{d(x)}{2} > 0, \quad (32a)$$

$$\frac{\partial(\pi_H - \pi_0)}{\partial F} = -\frac{1}{2} < 0. \quad (32b)$$

(ii). Straightforward since consumer surplus enters negatively in (31'').

QED

In Proposition 4, (i) implies that a rise in  $\gamma$ , or a reduction in  $F$ , increases  $\pi_{II} - \pi_0$ , pushing firms to move out ; (ii) arises because including consumer surplus increases the government's payoff at the threat point, improving its bargaining position against the firm. More intuitively, when the government cares about consumer surplus, it charges a lower pollution tax, as shown in (28a) and (28b), which reduces the incentives for firms to migrate.

Finally, let's turn to the changes of world welfare, which can be written as the sum of firm profits and the utilities of the two governments in the two countries.

$$\psi = 2(\pi + g) = 2\{u(x) - \gamma d(x) - F\}. \quad (33)$$

where  $u(x)$  is the utility from consuming output  $x$ , and the term  $u(x) - px$  is the consumer surplus. Because under mutual FDI output remains unchanged, from (33) world welfare decreases by twice the fixed cost. The changes in the negotiated tax rate through FDI simply redistribute the rents between the local government and the firms. We therefore obtain

**Proposition 5:** *The world welfare decreases by twice the fixed cost of FDI. Since firm profits increase after mutual migration, the decrease in the utility of the local governments exceeds the increase in firm profits.*

Thus, the country as a whole could lose from mutual FDI. As a theoretical possibility, governments could disallow such FDI. However, in the model we treat FDI as a decision by firms rather than by governments. Disallowing such FDI would be unimaginable in practice, especially in our setting of two developed countries.

## 6. Bargaining over Environmental Tax Only

In this section, we briefly investigate the case in which the firms can decide employment unilaterally, while only the environmental tax rate is negotiated. We demonstrate that the qualitative results of the model obtained so far remain robust.

### 6.1 No FDI

Under no FDI, firm profits, government utilities and the Nash bargaining product can still be written as in expressions (1a)~(3). However, in the U.S., the firm and the local government jointly maximize (3) by choosing  $t$  only, while simultaneously, the firm maximizes (1a) by choosing  $x$ . The first order conditions can be respectively written as:

$$p + xp' - t - c'(x) = 0, \quad (34a)$$

$$\pi - g = 0. \quad (34b)$$

Condition (34a) says that the firm equates marginal revenue to marginal cost, and condition (34b) is identical to (4b'), i.e., the firm and the local government divide the net bargaining gains equally.

Note that the level of employment (environmental damage) is different from those in the previous section, when it is bargained over. Here, it is determined by the firm only.

Actually, the firm does not care about the environmental damage when choosing output. However, it is forced to pay for the damage through the negotiated tax rate, determined by (34b). Given a negotiated tax rate, the firm produces a level of output such that the marginal revenue is equal to the tax rate.

## 6.2 Mutual FDI and One-Way FDI

Under mutual FDI, the local government negotiates with firms A and B separately but simultaneously over the tax rate, and still simultaneously the two firms maximize their own profits by choosing outputs. The functions for firm profits, government utilities, and the Nash products are still written as in (7a)~(10).

Under one-way FDI, there are three bargaining games worldwide, one in the U.S. and two in Europe. The Nash products and the threat-point payoffs can still be written as in conditions (16)~(20).

In all cases, output is determined unilaterally by the firm, while the tax rate is negotiated between the firm and the local government. We first derive the first order conditions, and then plug the values in (26) for the variables to obtain numerical solutions. The simulated profits are reported in table 3 below.

*Table 3: Positive Production Cost, and Bargaining over Taxes only*

Firm A \ Firm B	With FDI	Without FDI
	With FDI	Without FDI
With FDI	501-F, 501-F	651-F, 279
Without FDI	279, 651-F	417, 417

From table 3, we have

***Proposition 6:*** *If only the environmental tax rate is negotiated while employment is left for the firms to decide, mutual migration of polluting firms is the unique Nash equilibrium if the fixed cost is not too large.*

Even though the firms and the local government no longer maximize rents choosing out, what matters is how the realized rents are divided. As long as the tax rate is negotiated, the firm and the local government always divide the net bargaining gains according to their respective bargaining powers. The qualitative results remain valid regardless of if employment (environmental damage) is also negotiated or not.

## **7. Concluding Remarks**

In this paper, we have attempted to model the North-North migration of polluting firms. Environmental compliances and local employment are determined through bargaining between the firm and the local government. It has been shown that if the firm's payoff at the threat point is larger than that of the government, then mutual migration of dirty firms arises in equilibrium. The model predicts that the dirtier firms, and/or firms with highly inelastic demand are more likely to migrate to other countries. We also found that increases in the government's valuation of the environment, or in the degree of globalization (e.g., reductions in the cost of FDI) cause dirty firms to move out. The effect of a government caring about consumer surplus leads to a lower pollution tax, reducing firms' incentives to move out.

We assumed that both the tax rate and the level of employment are determined simultaneously. It is well known that if the tax rate is chosen in a prior stage, the level of

output (employment and environmental damage) becomes smaller. However, the mechanism generating mutual migration of dirty firms remains the same.

We have abstracted from investigating the case in which governments in different countries cooperate to set common regulations on the multinational firms. If governments can cooperate through multinational agreements, then their payoffs at the threat point increase relative to those of the firms.

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