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# A Theory of Strategic Vertical DFI and the Missing Pollution-Haven Effect

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**Summary**

This paper develops a theory of *strategic* vertical DFI (direct foreign investment) to suggest an explanation for the empirical puzzle of the missing `pollution-haven' effect. It focuses on a firm's strategic incentive to create multi-market interdependence (in addition to other conventional incentives for DFI) and suggests that the empirical investigations on pollution-haven effects based on environmental compliance costs might be complicated by such strategic behaviour. The theory provides particular implications for the empirical research in this area and some broader implications for the theory of DFI.

**Keywords**: Trade and environment, pollution-haven hypothesis, vertical DFI/FDI

**JEL**: F18

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## 1. Introduction

The so-called pollution-haven hypothesis has recently generated a lot of discussions in both political and academic circles. Although it is closely related to the literature of public economics on inter-jurisdictional competition for mobile factors, the recent focus is on the effects due to globalization. According to the hypothesis, in response to trade liberalization pollution-intensive industries will tend to move to the countries that have lax environmental regulations. Also, it is believed that the relocation of polluting industry and the effect of lax environmental regulations on comparative advantage will be reflected in trade patters.[1] Given that moving of industries is directly associated with investment and employment, the policy implications are inevitable since governments in different countries will have their concerns in designing environmental policies. However, empirical findings on the pollution-haven effect are negative, or very weak at most.[2] This creates an empirical puzzle - the missing pollution-haven effect (Levinson, 2000). One could search on the empirical front for the reasons why previous studies fail to find empirical support.[3] But in the absence of clear empirical evidence, it would be particular worthwhile to search on the theoretical ground for the reasons that may prevent us from finding the significant pollution-haven effect, and hopefully this could help identify some important factors that are needed to be considered in search of the pollution-haven effect. The present paper falls into the second category.

In my view the relocation of production of pollution-intensive products, described by the pollution-haven hypothesis, is essentially the multinationals' decisions on direct foreign

[1] In this paper we discuss the pollution-haven effect only in terms of plant-relocation. Theoretical work on the pollution-haven effects, from both angles, can be found in the theoretical work by McGuire (1982), Markusen, Morey and Olewiler (1993, 1995), Copeland and Taylor (1994), among others.

[2] See, among many others, Keller and Levinson (1999), Co and List (2000), and survey papers by Jaffe *et al* (1995), Levinson (1996), and Wilson (1996).

[3] There are two common explanations for the empirical finding of the missing pollution-haven effect (see Levinson, 1996, for a review of other explanations). First, the data quality on environmental compliance costs and environmental regulations across countries are poor; second, even with good data, environmental compliance costs are only a small part of total production costs.

investment (DFI).[4] Is there any theory behind the pollution-haven hypothesis? Yes, it is the classic theory of vertical direct foreign investment motivated by factor-endowment differences (Helpman, 1984). Therefore, in a broader perspective, to search for the pollution-haven effect we should ask what is the alternative theory. This is not necessarily for testing one theory against the other but simply because we need alternative theories to control for other important factors in empirical investigations. If the alternative theory is the theory of horizontal DFI, however, the missing pollution-haven effect should not be a surprise since according to many studies (e.g., Markusen and Maskus, 1999), overwhelming evidences support the theory of horizontal, rather than vertical, DFI.

However, the pollution-haven effect is meager even in apparently vertical DFI. For example, in their recent search of the pollution-haven effect, Smarznske and Wei (2001) uses the data on the DFI into the Central/Eastern Europe and former Soviet Republics, which certainly belongs to the pattern of North-South DFI. Also, we notice that many relocated pollution-intensive products are intermediate goods.[5] Moreover, according to Gorg and Ruane (1999), the output associated with DFI not only goes back to the parent companies but also is sold in the host countries/regions.

Noticing that large pollution-intensive industry tends to exist in oligopolist markets (Walter, 1982), in this paper we develop a theory of vertical DFI motivated by firms' strategic incentives rather than relative factor-endowment/price differences. Specifically, if the purchasers of the intermediate goods relocated in the host countries/regions directly or indirectly compete with the DFI parent company in the final-goods market, a firm may have strategic incentives to relocate the production of the intermediate good to create multi-market inter-dependance among rivals in the downstream market. This is especially relevant when the economies of scale prevent a firm from having two plants to produce an intermediate good in each location and the firm responds to the increase of trade liberal-

[4] In this current paper we use DFI (direct foreign investment), instead of FDI (foreign direct investment), to emphasize that we focus on multinational activities rather than aggregated capital flows.

[5] I am grateful to Shang-Jin.Wei for kindly providing me with the table of pollution-intensity index for 4-digit SIC industries in Smarznske and Wei (2001).

ization.

We consider a model where two firms, firm $H$ located in the home and firm $F$ located in the foreign country, produce a differentiated final product and compete in the home country. While paying a relative higher pollution tax at home, Firm $H$ owns a superior technology that produces an intermediate good with less pollution emission. Therefore, firm $H$ may have incentives to relocate its production of the intermediate good to the foreign country to reduce environmental compliance costs and to profit from selling the intermediate good to firm $F$. But more importantly, recognizing that they may compete in the final product market, firm $F$ has a strategic incentive in choosing the supplier of its intermediate input. This then creates an opportunity for firm $H$ to make a strategic move in relocating the production of the intermediate good as well as its pricing strategy for the intermediate good.

It is shown that there could exist three kinds of motivations for such DFI: (i) to reduce environmental compliance costs - the element of the pollution-haven hypothesis, (ii) to profit from selling intermediate goods, and more importantly, (iii) to soften competition with rivals in the final goods market. The combination of the three may explain why most studies did not find significant pollution-haven effect. Our theory of strategic vertical DFI, however, have also provided some useful implications for the empirical investigation of the pollution-haven effect.

Our main results and implications are as follows. First, strategic DFI would not arise when trade costs are high. Globalization creates an opportunity for multimarket contact and, as a result, strategic DFI may arise. Firm $H$ would relocate production of the dirty good abroad even when the trade-off between lower compliance costs and transport costs does not exist. This is not only because firm $H$ can sell the intermediate good to firm $F$ but more importantly, it can charge a high price, even higher than a competitive supplier. The reason for this is due to the collusive effect of multimarket inter-dependence. Second, such collusive effect is also reflected in the prices of the final good. Relocation of dirty production abroad reduces environmental compliance costs of production but this does not imply that it would reduce the prices of the final good. Third, the market size/demand

for the intermediate good in the foreign country is endogenous in the presence of strategic interaction. Therefore, in addition to the GDP, a better proxy (e.g., estimating the derived demand for the intermediate good) is needed to control for (relative) market size. Finally, the current theory suggests that we should separate intermediate goods from final products when we use the data of multinationals' DFI and if possible, take into account any possible multimarket inter-dependance.

There have been little theoretical work on the reasons for the missing pollution-haven effect.[6] Antweiler, Copeland and Taylor (2001) recognize that pollution intensive industries usually are also capital intensive, and richer countries are also relatively capital-abundant. Therefore, in the Heckscher–Ohlin framework, the factor-endowment effect works against the income effect (i.e., richer countries also have stricter environmental regulations since the environment is a normal good). Therefore, free trade may move the production of dirty goods to the countries with stricter pollution regulation. Using data on sulfur dioxide concentrations from the Global Environmental Monitoring Project, they also find empirical support for their theory. Their study offers an explanation why one should not expect to find the pollution-haven effect in aggregate trade data. Many studies based on the DFI data, however, also find little evidence that multinationals are drawn to pollution havens.[7] The present paper offers an explanation for the missing pollution-haven effect in the multinationals' DFI.

Using theory of horizontal DFI, Markusen (1996) also shows that trade liberalization increases production sensitivity to costly environmental regulations but multinationals do not increase the production-reallocation effect caused by environmental restrictions. The reason is that multinationals can smooth the effects of the cost increases in one country over both countries. Hoel (1997), on the other hand, examines how endogenous plant locations would affect government environmental policy. Ulph and Valentini (1997) also analyze

[6]Bommer (1999) shows that firms may strategically relocate parts of their production abroad following an increase in domestic environmental regulations. In his paper the strategic relocation acts as a signalling to convince domestic policymakers to refrain from future tightening of environmental standards.

[7]See Walter (1982), Leonard (1988), Grossman and Krueger (1993), and Eskeland and Harrison (1997).

strategic environmental policy in the presence of agglomeration effects of inter-sectorial (input-output) linkages. Unlike these studies, this current paper firms' strategic incentives for vertical DFI.

The research interests on vertical DFI has recently grown substantially although the bulk of the literature on multinationals are still on horizontal DFI.[8] However, the literature on vertical (upstream) DFI, focuses on firms' incentives to reduce the costs of their own inputs or/and raise those of their rivals (e.g., Konan, 2000). The key insight of these studies are similar to those in the literature on vertically related markets in international trade, as such Spencer and Jones (1991, 1992). In our paper the output of vertical DFI not only goes back to its parent firm but also serves the local market. More importantly, however, the incentive for DFI in our model is not just to have the market-access of selling intermediate products, rather, is to create an opportunity for multi-market contact in order to soften competition in the final goods market. Therefore, the present paper itself is a contribution to the literature on vertical DFI.

The rest of the paper is organized as follows. Section 2 analyzes the subgame with and without DFI. Section 3 analyzes the effects of globalization on the equilibrium outcome (DFI versus no-DFI) and the implications of strategic DFI for the (missing) pollution-haven effects. Section 4 discusses the assumptions and the robustness of our results. Section 5 concludes the paper.

## 2. The Model

We have two countries: Home and Foreign. There are two firms, firm $H$ located in the home and firm $F$ located in the foreign country. Each firm produces a (downstream) differentiated product, $Y$, sold in the home country although it could also be in a "third-market". The demand for the two firms' products is $q^i\left(p^i, p^j\right)$, $i, j = H, F$. We assume that the products are imperfect substitutes and demand for a product is more responsive to its own price than to the price of the other product, i.e., $0 < \partial q^i\left(p^i, p^j\right)/\partial p^j < -\partial q^i\left(p^i, p^j\right)/\partial p^i$. As-

[8] E.g., Markusen, *et al* (1996), and Roy and Viaene (1998).

sume that production of good $Y$ requires using a homogeneous intermediate good, $X$, and for simplicity, there is no other variable costs of production for goods $Y$ and $X$. But there is a by-product associated with production of good $X$ - pollution, which is subject to an environmental tax., $\tau^i$ $(i = H, F)$. Good $X$ is competitively available in the foreign country with the technology that generates $e^F$ units of pollution for each unit the output. Firm $H$ in the home country, however, owns a superior technology that generate only $e^H$ $(e^H < e^F)$ units of pollution for producing each unit of good $X$ and is vertically integrated.[9]

As depicted in Figure 1, the game has 3 stages and it proceeds as follows. In the first stage firm $H$ decides whether to move the production of the intermediate good $X$ to the foreign country (i.e., DFI). There are trade costs for both goods $X$ and $Y$. If firm $H$ decides to relocate production of good $X$ to the foreign country, it will have to pay transport costs (or tariff) for shipping back good $X$. In the second stage firm $H$ commits to a (producer) price, $r$, for the intermediate good (if it sells $X$); and firm $F$ decides whether to contract to buy the intermediate good from firm $H$ or from a competitive domestic supplier.[10] In the third stage the two firms compete in price (Bertrand) in the downstream market located in the home country (we will briefly discuss quantity competition in Section 4).

**(Figure 1 goes here).**

The subgame perfect equilibrium of the model is solved by backward induction. We first characterize the subgame in which firm $H$ keeps production of good $X$ in the home country (i.e., no-DFI) and the subgame in which firm $H$ relocates the production of good $X$ to the foreign country (i.e., DFI). Section 3 then analyzes the first stage of the game to examining how the equilibrium is determined. Before proceed, however, we need the following three assumptions..

First, to keep the standard incentive for vertical DFI, we assume $\tau^H > \tau^F$ but it will become clear later that this is not essential for strategic DFI to arise. Second, we assume

[9] In this paper we do not model the benefits of a cleaner environment. Also, for simplicity we do not introduce pollution abatement into the model.

[10] Thus, we are assuming that $F$ can commit to purchase all input from $H$. The implications of relaxing this assumption is discussed in Section 4.

that $e^H < e^F$. Third, we assume that $\tau^H e^H + t_x^F > \tau^F e^F$ where $t_x^F$ is the tariff-cum-transport cost if firm $F$ imports the intermediate good. That is, if firm $H$ does not relocate production of good $X$, firm $F$ would not find it profitable to buy the intermediate good from firm $H$.

### 2.1 Subgame under no-DFI

Suppose that firm $H$ keeps production of the intermediate good $X$ in the home country and firm $F$ purchases good $X$ from a competitive domestic supplier at price equal to $\tau^F e^F$. Then the profit functions for firms $F$ and $H$ are

$$\pi^F = [p^F - (t_y + \tau^F e^F)]q^F(p^F, p^H) \tag{1}$$

and

$$\pi^H = (p^H - \tau^H e^H)q^H(p^H, p^F) - G, \tag{2}$$

where $t_y$ is the tariff-cum-transport cost for good $Y$. We have dropped superscript $H$ in $t_y$ (and later $t_x$). The superior technology of producing good $X$ requires a fixed cost $G$ and we assume that the presence of economies of scales prevent firm $F$ from having two plants to produce good $X$. Producing good $X$ with the inferior technology (i.e., with emission $e^F$) does not require any fixed cost.

The equilibrium prices, which are assumed to exist uniquely for any given value of a set of parameter, $\{\tau^H, \tau^F, e^H, e^F, t_y, G\}$ and are denoted as $\overline{p}^i(\overline{c}^i, \overline{c}^j)$, where $\overline{c}^H \equiv \tau^H e^H$ and $\overline{c}^F \equiv t_y + \tau^F e^F$ satisfy the following first-order conditions:

$$q^F\left(\overline{p}^F, \overline{p}^H\right) + [\overline{p}^F - (t_y + \tau^F e^F)]q_1^F\left(\overline{p}^F, \overline{p}^H\right) = 0, \tag{3}$$

$$q^H\left(\overline{p}^H, \overline{p}^F\right) + (p^H - \tau^H e^H)q_1^H\left(\overline{p}^H, \overline{p}^F\right) = 0. \tag{4}$$

Denote the equilibrium profits by $\overline{\pi}^F\left(\overline{c}^F, \overline{c}^H\right)$ and $\overline{\pi}^H\left(\overline{c}^H, \overline{c}^F\right)$.

### 2.2 Subgame under DFI

Now suppose that firm $H$ has relocated its production of the intermediate good $X$ to the foreign country. Assume that firm $H$ commits a price, $r$ (where $r > \tau^F e^H$),[11] for the intermediate good $X$ if it sells the good. Then firm $S$ decides whether to contract to buy all the intermediate good from either firm $H$ or a competitive domestic supplier.

If firm $F$ purchases the intermediate good $X$ from a competitive domestic supplier, the profit functions for $F$ and $H$ are

$$\widehat{\pi}^F = [p^F - (t_y + \tau^F e^F)]q^F(p^F, p^H) \tag{5}$$

and

$$\widehat{\pi}^H = [p^H - (t_x + \tau^F e^H)]q^H(p^H, p^F) - G. \tag{6}$$

where $t_x$ is the tariff-cum-transport cost for good $X$ when firm $H$ ships back good $X$. We have assumed that the fixed cost of producing good $X$ is the same in both the home and the foreign countries to rule out other possible trade-offs for DFI (e.g., Markusen, Morey and Olewiler, 1993). We also assume that $t_x < t_y$ (i.e., it costs more to ship a final product than a component, or, the specific tariff for the final good is relatively high because of the high value-added in the final good.) so that firm $H$ will not move both the upstream and downstream productions all together to the foreign country. The equilibrium prices, which are assumed to exist uniquely for any values of a given set of parameters, $\{\tau^H, \tau^F, e^H, t_y, t_x, G\}$ and are denoted as $\widehat{p}^i\left(\widehat{c}^i, \widehat{c}^j\right)$, where $\widehat{c}^H \equiv t_x + \tau^F e^H$ and $\widehat{c}^F = \overline{c}^F \equiv t_y + \tau^F e^F$ satisfy the following first-order conditions:

$$q^F\left(\widehat{p}^F, \widehat{p}^H\right) + [\widehat{p}^F - (t_y + \tau^F e^F)]q_1^F\left(\widehat{p}^F, \widehat{p}^H\right) = 0, \tag{7}$$

$$q^H\left(\widehat{p}^H, \widehat{p}^F\right) + [\widehat{p}^H - (t_x + \tau^F e^H)]q_1^H\left(\widehat{p}^H, \widehat{p}^F\right) = 0. \tag{8}$$

[11] It will become clear that it would never be optimal for firm $H$ to sell the intermediate good at a price less than its marginal cost of production.

Denote the equilibrium profits by $\widehat{\pi}^F\left(\widehat{c}^F,\widehat{c}^H\right)$ and $\widehat{\pi}^H(\widehat{c}^H,\widehat{c}^F)$.

If firm $F$ contracts to buy the intermediate good $X$ from firm $H$ at price equal to $r$ , the profit functions for $F$ and $H$ are

$$\widetilde{\pi}^F = [p^F - (t_y + r)]q^F(p^F, p^H) \tag{9}$$

and

$$\widetilde{\pi}^H = [p^H - (t_x + \tau^F e^H)]q^H(p^H, p^F) - G + (r - \tau^F e^H)q^F(p^F, p^H) \tag{10}$$

respectively. The equilibrium prices, which are assumed to exist uniquely for any values of a given set of parameters, $\{\tau^F, e^H, t_y, t_x, G\}$ and are denoted as $\tilde{p}^i(\widetilde{c}^i, \widetilde{c}^j)$, where $\widetilde{c}^H = \widehat{c}^H \equiv t_x + \tau^F e^H$ and $\widetilde{c}^F \equiv t_y + r$ , satisfy the following first-order conditions:

$$q^F\left(\tilde{p}^F, \tilde{p}^H\right) + [\widetilde{p}^F - (t_y + r)]q_1^F(\tilde{p}^F, \tilde{p}^H) = 0, \tag{11}$$

$$q^H\left(\tilde{p}^H, \tilde{p}^F\right) + [\widetilde{p}^H - (t_x + \tau^F e^H)]q_1^H(\tilde{p}^H, \tilde{p}^F) + (r - \tau^F e^H)q_2^F(\tilde{p}^F, \tilde{p}^H) = 0 \tag{12}$$

Denote the equilibrium profits by $\tilde{\pi}^F\left(\widetilde{c}^F,\widetilde{c}^H\right)$ and $\tilde{\pi}^H(\widetilde{c}^H,\widetilde{c}^F;r)$. We assume that firm $F$ purchases good $X$ from firm $H$ would be an equilibrium if no firm is worse off and at least one firm has higher profit than otherwise would be.

Notice that $\widetilde{c}^F \equiv t_y + r$ is the effective marginal cost for firm $F$. Obviously, for any $r$ that yields positive outputs for both firms, an increase in $r$ would increase the prices for the final goods. That is,

$$\frac{\partial \tilde{p}^F\left(\widetilde{c}^F,\widetilde{c}^H\right)}{\partial r} = \tilde{p}_1^F\left(\widetilde{c}^F,\widetilde{c}^H\right) > 0 \,\text{and}\, \frac{\partial \tilde{p}^H\left(\widetilde{c}^H,\widetilde{c}^F\right)}{\partial r} = \tilde{p}_2^H\left(\widetilde{c}^H,\widetilde{c}^F\right) > 0\,. \tag{13}$$

It is less clear how $\tilde{\pi}^F\left(\widetilde{c}^F,\widetilde{c}^H\right)$ will change as $r$ or the tariffs change. From the envelope theorem, we have

$$\frac{\partial \tilde{\pi}^F\left(\widetilde{c}^F,\widetilde{c}^H\right)}{\partial r} = -q^F\left(\tilde{p}^F,\tilde{p}^H\right) + [\widetilde{p}^F - (t_y + r)]\frac{\partial q^F(\tilde{p}^F,\tilde{p}^H)}{\partial \tilde{p}^H}\frac{\partial \tilde{p}^H\left(\widetilde{c}^H,\widetilde{c}^F\right)}{\partial r},$$

where the first term is negative while the second term is positive. A higher input price for $F$ has the direct effect of cost increase on $F$, which reduces $F's$ profit; but it also has the indirect effect of increasing $H's$ price for the final good, which benefits $F$. However, as in Chen (forthcoming) and others, the direct effect dominates provided that $0 < \partial q^i\left(p^i, p^j\right)/\partial p^j < -\partial q^i\left(p^i, p^j\right)/\partial p_i$ (an assumption discussed earlier). Thus, $F's$ equilibrium profit decreases in its input costs:

$$\frac{\partial \tilde{\pi}^F\left(\tilde{c}^F, \tilde{c}^H\right)}{\partial r} < 0\,. \tag{14}$$

Similarly, using the envelope theorem we have

$$\begin{aligned} & \frac{\partial \tilde{\pi}^H(\tilde{c}^H, \tilde{c}^F; r)}{\partial r} \\ = \quad & \{[\tilde{p}^H - (t_x + \tau^F e^H)]\frac{\partial q^H(\tilde{p}^H, \tilde{p}^F)}{\partial \tilde{p}^F} + (r - \tau^F e^H)\frac{\partial q^F(\tilde{p}^F, \tilde{p}^H)}{\partial \tilde{p}^F}\}\frac{\partial \tilde{p}^F\left(\tilde{c}^H, \tilde{c}^F\right)}{\partial r} + q^F\left(\tilde{p}^F, \tilde{p}^H\right), \end{aligned}$$

which again can have ambiguous signs but will be assumed positive for the $r$ that is in the relevant range of our analysis.[12] That is, we assume

$$\frac{\partial \tilde{\pi}^H(\tilde{c}^H, \tilde{c}^F; r)}{\partial r} > 0, \tag{15}$$

or $H's$ equilibrium profit increases in $r$ when it sells the input to $F$. Both conditions (14) and (15) are satisfied with linear-demand functions.

Therefore, given the game specified above, firm $H$ will optimally set its $r$ such that the profit of firm $F$ purchasing good $X$ from firm $H$ is the same as (or slightly higher than) that of purchasing it from a competitive domestic supplier.[13] We therefore have:

**Proposition 1** *In the subgame of DFI, firm $F$ will always buy the intermediate good $X$ from firm $H$, rather than a competitive domestic supplier. In equilibrium we have $\tilde{p}^i > \widehat{p}^i$ $(i = H, F)$, $\tilde{\pi}^H\left(t_x + \tau^F e^H, t_y + r^*; r^*\right) > \widehat{\pi}^H\left(t_x + \tau^F e^H, t_y + \tau^F e^F\right)$ and*

[12] Notice that the sign is positive when the difference between $r$ and $\tau^F e^H$ is not too large.

[13] Thus, we are assuming that firm F has all the bargaining power. The implications of a more general Nash bargaining solution are discussed in Section 4.

$\tilde{\pi}^F\left(t_y + r^*, t_x + \tau^F e^H\right) = \widehat{\pi}^F\left(t_y + r^*, t_x + \tau^F e^H\right)$, *where* $r^*$ *is the equilibrium price of the intermediate good* $X$ *and is greater than* $\tau^F e^F$.

**Proof:** It is not difficulty to understand that firm $F$ will purchase good $X$ from firm $H$ if $r < \tau^F e^F$. Now suppose that $r = \tau^F e^F$ initially. Then firm $F$'s best response function would be the same as that if it buys good $X$ from a competitive domestic supplier (i.e., eqs 7 and 11 are the same). From (8) and (12), however, notice that firm $F$'s best response function is $\widehat{\pi}_1^F = 0$ when firm $F$ purchases good $X$ from a competitive domestic supplier but it becomes $\widehat{\pi}_1^F + (r - \tau^F e^H)(\partial q^F/\partial p^H) = 0$ when firm $F$ purchases good $X$ from firm $H$. Since $(r - \tau^F e^H)(\partial q^F/\partial p^H) > 0$, it shifts up firm $H$'s reaction function resulting in higher prices (i.e., $\tilde{p}^i > \widehat{p}^i$, $i = H, F$). This is illustrated by a upward shift of firm $H$'s reaction function to the middle dashed-line in Figure 2. The higher prices soften the competition in the final-good market and increase the profits of both firms. However, firm $H$ only need to keep firm $F$ being indifferent (or slightly better-off) from its alternative. From (14) and (15), this then enables firm $H$ to raise $r$ beyond the level of $\tau^F e^F$ until $\tilde{\pi}^F\left(t_y + r^*, t_x + \tau^F e^H\right) = \widehat{\pi}^F\left(t_y + \tau^F e^F, t_x + \tau^F e^H\right)$. This is represented in Figure 2 by a further upward shift of firm $H$'s reaction function, together with a right shift of firm $F$'s reaction function (since an increase in $r$ raises firm $F$'s marginal cost). ■

(**Figure 2 goes here**)

It is surprising that firm $F$ actually pays more for good $X$ when it buys the intermediate good from firm $H$. The key to understand this is to recognize that firm $H$ would have less incentive to cut its price in the final good market if firm $F$ buys the intermediate good from firm $H$. Firm $F$ would strictly prefer to buy the intermediate input from firm $F$ if the cost of imports is the same. This then enables firm $H$ to raise the price of good $X$. This type of collusive effects is in spirit similar to that in Chen, Ishikawa, and Yu (2001) where strategic outsourcing arises because of the multimarket contact. But in that paper we show that such strategic outsourcing would never occur under an assumption similar to that of $\tau^H e^H + t_x^F > \tau^F e^F$ in the current paper. Proposition 1, however, shows that firm $H$'s

decision on *strategic DFI* could effectively create an opportunity for such a multimarket contact even when the conditions for strategic outsourcing are absent.

### 3. Globalization and DFI: re-examining the pollution-haven hypothesis

Now we solve for the equilibrium decision in the first stage and show how globalization could create an opportunity for strategic DFI. Although we choose transport costs to discuss, we interpret a decrease in their levels more broadly as a movement towards globalization. More specifically, we want to show that the level of $t_x$ will determine what kind of equilibria to occur.

**Proposition 2** *(i) The subgame perfect equilibrium is DFI (resp. no-DFI) if* $t_x < \widetilde{t}_x$ *(resp.* $t_x > \widetilde{t}_x$*), where* $\widetilde{t}_x$ *satisfies* $\tilde{\pi}^H\left(\widetilde{t}_x + \tau^F e^H, t_y + r^*; r^*\right) = \overline{\pi}^H\left(\tau^H e^H, t_y + \tau^F e^F\right)$*;*
*(ii)* $\widetilde{t}_x > \tau^H e^H - \tau^F e^H$.

**Proof:** (i) The first part is straightforward when noticing that $\tilde{\pi}^H\left(t_x + \tau^F e^H, t_y + r^*; r^*\right)$ is decreasing in $t_x$. Therefore, firm $F$ will find it profitable (i.e., $\tilde{\pi}^H > \overline{\pi}^H$) to relocate production of good $X$ in the foreign country as long as $t_x < \widetilde{t}_x$ (ii) Suppose that $t_x = \tau^H e^H - \tau^F e^H$ (i.e., $t_x + \tau^F e^H = \tau^H e^H$) initially. It is then straightforward to show that $\tilde{\pi}^H\left(\tau^H e^H, t_y + r^*; r^*\right) > \overline{\pi}^H\left(\tau^H e^H, t_y + \tau^F e^F\right)$ because $r^* > \tau^F e^F$ (from Proposition 1). Therefore, in equilibrium $\widetilde{t}_x$ must be greater than $\tau^H e^H - \tau^F e^H$. ■

When trade costs are high, strategic relocation of production of good $X$ would not occur. When trade costs become lower, strategic relocation/DFI arises. Notice that when $t_x < \tau^H e^H - \tau^F e^H$, the relocation is consistent with the pollution-haven hypothesis. Firm $H$ relocates its dirty production to the foreign country that has lower environmental tax ($\tau^F < \tau^H$) and also reduces the total cost of good $X$ (including transport cost). This is the trade-off and the incentive for conventional vertical DFI, which is the focus of the pollution-haven hypothesis.

However, the pollution-haven effect may not be identified because Proposition 2 also allows for $t_x \in (\tau^H e^H - \tau^F e^H, \widetilde{t}_x)$. When $\tau^H e^H - \tau^F e^H < t_x < \widetilde{t}_x$, the trade-off between

the difference in factor prices and trade cost no longer exists. Therefore, relocation of production of good $X$ should not occur if we focus only on the incentives for conventional vertical DFI. Nevertheless, strategic relocation will arise (even if $\tau^F \geq \tau^H$, i.e., no incentive for conventional vertical DFI).[14] Thus empirical investigations on pollution-haven effects based on environmental compliance costs could be complicated by the presence of strategic DFI, even with good data on other production costs.

**Corollary 1** *(i) When $t_x < (\tau^H - \tau^F)e^H$, the relocation of production of good $X$ is consistent with the pollution-haven hypothesis; (ii) when $(\tau^H - \tau^F)e^H < t_x < \widetilde{t}_x$, however, the pollution-have effect would not be identified under the traditional theory of vertical DFI motivated by factor-endowment (or factor-price) differences.*

On the other hand, however, the element of the pollution-haven hypothesis is reflected in the relationship between the decision of the relocation and the gap in the two environmental taxes. The easiest way to show this is to normalize $\tau^F \equiv 1$ and examine the effects of an increase in $\tau^H$. Notice that an increase in $\tau^H$ (i.e., the gap of $\tau^H - \tau^F$) will lower $\pi^H\left(\tau^H e^H, t_y + \tau^F e^F\right)$ but leaves $\tilde{\pi}^H\left(\widetilde{t}_x + \tau^F e^H, t_y + r^*; r^*\right)$ unchanged. Thus, for some level of $t_x$, relocating production of good $X$ was initially not profitable but now could become profitable. Therefore, $\widetilde{t}_x$ could go up and thus we have the next proposition.

**Proposition 3** *Under the theory of strategic vertical DFI, it is still true that the larger the gap of the environmental taxes between the home and foreign countries, the more likely will firm $H$ relocate its production of good $X$ abroad.*

Therefore, there still is a pollution-haven effect but the presence of strategic DFI could make it difficult to be identified. Our analysis, however, has the following implications for the empirical investigation of the pollution-haven effect. First, it probably helpful to separate final products from intermediate products since the latter is more likely to create

[14] It is not difficult to see that even if $\tau^F \geq \tau^H$, strategic DFI could still occur since $\tau^F e^H < \tau^F e^F$.

multi-market interdependence. Second, since most international intermediate-good markets are not competitive (often are oligopolistic) and hence multi-market contact could arise, GDP may not be able to capture the effect of (relative) market size.[15] GDP could be a good candidate if we deal with final products but for non-competitive intermediate-good markets, we need a better proxy to capture market/demand size. Furthermore, the market size for intermediate goods could become endogenous in the presence of multi-market interdependence.

In addition, as shown in the next proposition, the complication of strategic vertical DFI is also reflected in the final-good market in the search of the pollution-haven effect.

**Proposition 4** *Strategic relocation/DFI could increase the prices of the final good even when the foreign country has a lower environmental tax.*

**Proof:** To show this we just need to find a sufficient condition. Suppose $(\tau^H - \tau^F)e^H < t_x < \widetilde{t}_x$. Then it is straightforward to show that $\widehat{p}^H > \overline{p}^H$ since the marginal cost is higher (i.e., $\widehat{c}^H > \overline{c}^H$). Together with Proposition 1, this means that $\widetilde{p}^H > \overline{p}^H$. In addition, since $t_y + r^* > t_y + \tau^F e^F$ and they are the marginal costs for firm $F$, we then must have $\widetilde{p}^F > \overline{p}^F$ as well. ■

This is an interesting result. Firm $H$ relocates its dirty production abroad and reduces its environmental compliance costs of production. But this does not imply that such a relocation would reduce the prices of the final good in the home country.[16]. Ironically, the prices of the final good could go up due to the collusive effect of multimarket contact created by the strategic relocation.

Moreover, if we focus only on conventional vertical DFI, a more efficient firm (i.e., with lower $e^H$) would have less incentives to move its production abroad because the saving in the compliance costs becomes smaller relative to the cost of relocation. In our model, however, a lower $e^H$ on the other hand would increase the gain from selling the intermediate good

[15] The current empirical studies in the literature use GDP to capture the effect of market size on DFI flow or plant-relocation decision.

[16] If we model the public bad of pollution emission in this model, the home country would benefit from less pollution if pollution is not fully transboundary.

and, therefore, encourages firm $H$ to relocate production of good $X$ abroad. Therefore, we have

**Remark 1** *It is not necessarily true that a less efficient firm is more likely to migrate to a pollution haven.*

## 4. Discussion

The collusive behavior of the multimarket contact is revealed most clearly by the Bertrand assumption for competition in the final good market. First, it is important to realize that the collusive effect of strategic vertical DFI identified in this paper relies on firm $H$ taking into account the profit from the intermediate-good market. Specifically, firm $H$ realizes how its price of the final good will affect the quantity sold by the other firm (and hence the quantity of the intermediate good that firm $F$ would purchase from firm $H$). Thus such a collusive effect would not arise in Cournot competition (with a homogeneous final product).[17] With Cournot assumption, firm $H$ takes firm $F's$ output as given when deciding its own output. Therefore, although we would still have that $t_x + \tau^F e^H > \tau^H e^H$ (i.e., the trade-off between lower compliance costs and transport costs does not exist) since firm $H$ can make profits by supplying good $X$ to firm $F$, the price of good $X$ can not be above the competitive price.[18] More importantly, firm $H$ would take the (external) demand for good $X$ as exogenous in making its decision under Cournot assumption but endogenous under Bertrand competition. Therefore, our theory of strategic vertical DFI suggests that in addition to the GDP which was used to control for market size in almost all the studies in the literature, a better proxy

[17] Nevertheless, it is not difficult to see that the collusive behavior could still arise in quantity competition if firm $H$ is a Stackelberg leader in quantity in the final-good market. As a Stackelberg leader, firm $H$ would then incorporate the effect of its strategic action in the final-good market on its profit of selling the intermediate good to firm $F$. Thus the collusive incentive of strategic vertical DFI can again arise.

[18] If one believes that firm $H$ would realize that its strategic action in the final product market could affect its profit from the intermediate good market, then the Cournot assumption would seem inappropriate for our analysis.

(e.g., estimating the derived demand for the intermediate good) is needed to control for (relative) market size in empirical investigation of the pollution-haven effect.

In the model, firm $H$ is the only integrated firm that has lower marginal cost to produce the intermediate good and hence we have assumed that firm $H$ has all the bargaining power in the intermediate good market. Such a strong bargaining power [i.e., firm $H$ makes a "take-it-or-leave-it" offer and sets price $r$ such that $\tilde{\pi}^F\left(t_x+\tau^F e^H, t_y+r^*\right) = \widehat{\pi}^F\left(t_x+\tau^F e^H, t_y+\tau^F e^F\right)$] will be weakened if there were more than one such efficient firms or suppliers of the intermediate good. The assumption used in the paper allows us to derive the results in a very clear way. It is not difficult to see, however, that as long as firm $H$'s bargaining power is sufficiently strong, the qualitative nature of our results will not change in a more general bargaining framework. It is possible for firm $H$ to have a sufficiently strong bargaining/market power in the intermediate market if other firms are much less efficient.

## 5. Conclusion

In this paper we have identified a strategic incentive for vertical DFI, which arises from multi-market interdependence among firms. It is shown that globalization may create opportunities for multi-market interdependence and cause strategic vertical DFI to occur. Focusing on strategic vertical DFI is relevant and important because most relocations of pollution-intensive production are essentially the direct foreign investment by multinationals and many products relocated are intermediate products.

Our analysis suggests that the empirical investigations on pollution-haven effects based on environmental compliance costs could be complicated by the presence of strategic vertical DFI. Two implications are as follows. Since the incentive for strategic vertical DFI is very different from that for horizontal DFI, we probably should separate final products from intermediate products in search of the pollution-haven effect. Presumably, the pollution-haven effect is less difficult to identify with data on final products.

Second, With intermediate products and in the presence of possible multi-market inter-

dependences, GDP is no longer a good proxy to control for market size. In addition to the GDP, a better proxy (e.g., estimating the derived demand for intermediate products) is needed to control for (relative) market sizes in empirical investigation of the pollution-haven effect.

Finally, as mentioned earlier, it is not essential to assume that $\tau^H > \tau^F$ for the results in the paper. We use this assumption only to keep the standard incentive for vertical DFI. Therefore, recognizing firms' incentives to create multi-market contact, rather than to reduce environmental compliance costs, could shed light on the fact that "to the extent that the developed countries are exporting their dirty industries, they seem to be exporting them to each other, not to the less developed economies." (Repetto, 1995; quoted by Nordstrom and Vaughan, 1999). More broadly, it is well-know that flows of direct foreign investment seem do not respond to the difference in relative factor endowment/price (e.g., Markusen, 1995). This, however, did not create an "empirical puzzle" since most literature on foreign direct investment focus on horizontal DFI. The current paper suggests an alternative explanation based on a theory of vertical DFI.[19]

[19] See Yu (2001) for more about this.

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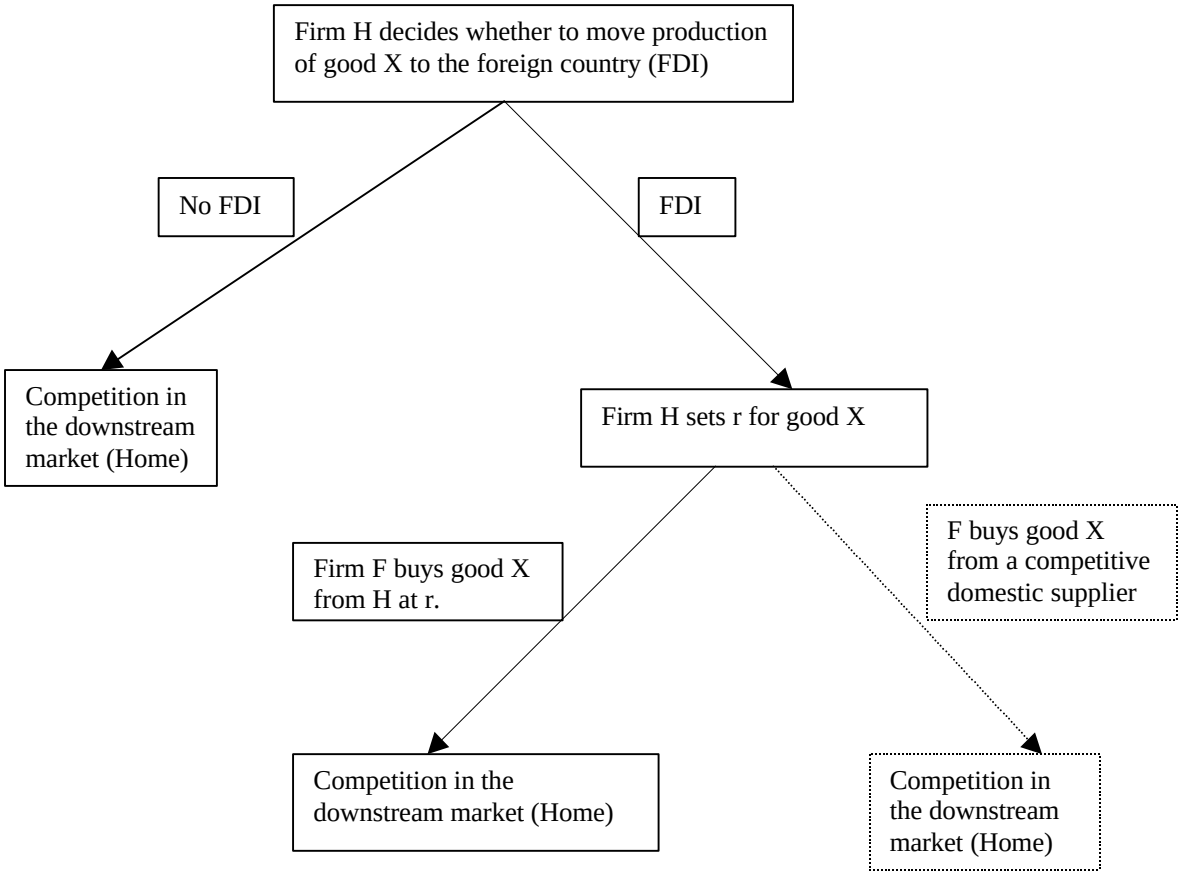
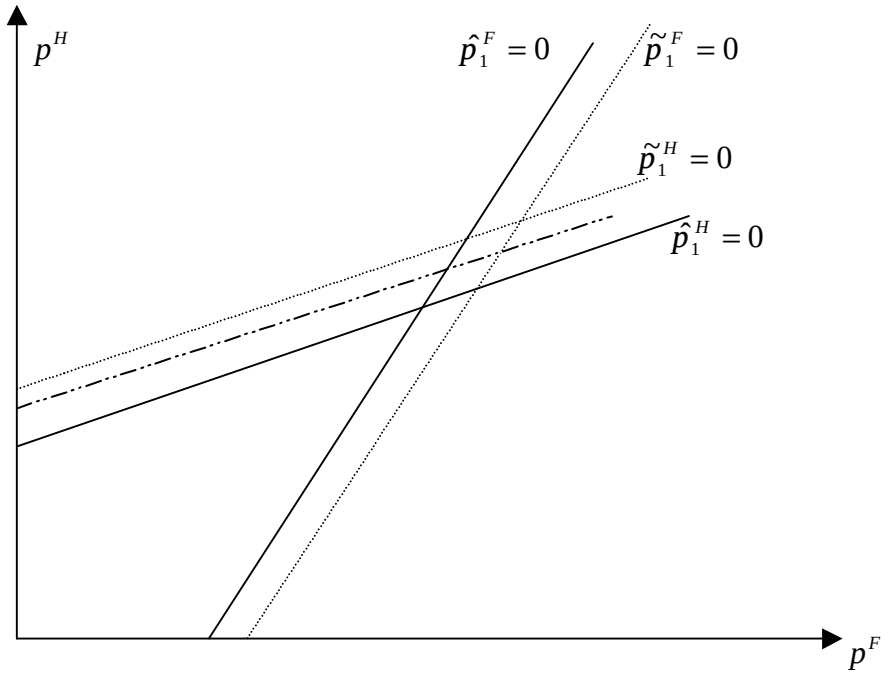



**Figure 1: The Game**




$$\hat{p}_1^F = (p^F - t^F e^F - t_y)\frac{\partial q^F}{\partial p^F} + q^F$$

$$\tilde{p}_1^F = (p^F - r - t_y)\frac{\partial q^F}{\partial p^F} + q^F$$

$$\tilde{p}_1^H = \hat{p}_1^H + (r - t^F e^H)\frac{\partial q^F}{\partial p^H}$$

**Figure 2**

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