Multinational Firms and FDI Environmental Taxes*

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A simple three-stage game model of a Cournot international duopoly, consisting of domestic and foreign multinational firms whose FDI cause transboundary environmental damage, is established to examine the optimal FDI environmental taxes. While the governments determine their FDI environmental taxes in the first stage, the firms endogenously choose their FDI sizes in the second stage and their output-export levels in the third stage. This paper finds some interesting results including that NIMBY (not in my back yard) problems disappear, and that the FDI environmental taxes are used as tools to implement strategic, as well as environmental, policies and can be negative in some cases.

1. Introduction

Nowadays, almost all large firms are oligopolistic multinational firms that have subsidiary plants set up by foreign direct investment (henceforth, FDI) in multiple countries. They account for a significant portion, not only of goods supply, but also of environmental damage in the world economy. This is one reason why some governments impose various environmental policies on big multinational firms. However, to be able to propose the appropriate environmental policies for such firms, it is necessary to first investigate them by constructing an international duopoly model of multinationals that cause global environmental damage, since such big multinational firms behave quite differently from uninational firms as well as perfectly competitive firms.

Among environmental models that investigate the impact of environmental policies on FDI decisions of multinational firms, Markusen *et al.* (1993 & 1995) have established a two-stage game model that analyzed the effect of environmental tax on plant locations of the multinationals and presented some remarkable results. However, their results are not applicable to some industries, because they adopted several restrictive assumptions. In

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the real world, there are some industries for which their assumptions are not plausible. Hence, before establishing our model, we shall examine their main assumptions, which are modified in this paper.

First, Markusen *et al.* have assumed that while plant locations are endogenously chosen, plant sizes are exogenously determined and that firms easily move both their parent and subsidiary plants anywhere in the world (that is, they are 'footloose'). However, most firms in the actual world decide not only plant locations but also plant sizes endogenously when they make FDI decisions. Moreover, almost all firms that are planning to construct plants in foreign countries by using FDI (henceforth, subsidiary plants) already have operating plants in their own countries (henceforth, parent plants), and such firms would not move their parent plants across borders as easily as they do subsidiary plants. Therefore, in the interests of realism, it is assumed in this paper that firms intending to build subsidiary plants in other countries have already parent plants in the original countries when the game begins and would not change the locations of the parent plants through the game.[1]

Second, though Markusen *et al.* have discussed environmental taxes based on output (henceforth, output environmental taxes), they have never considered environmental taxes based on FDI (henceforth, FDI environmental taxes). This is why they have considered environmental damage stemming from producing outputs (henceforth, output environmental damage), but they have ignored environmental damage stemming from constructing plants by FDI (henceforth, FDI environmental damage). In the present world there are many industries that generate serious FDI environmental damage as well. Therefore, we shall introduce FDI environmental damage into our model.

However, considering that some industries have considerably reduced output environmental damage (pollution emission, for example) since the imposition of output environmental taxes, it is expected that many firms will address the issue of output environmental damage in the not too distant future. Then, in such cases, FDI environmental damage would be more serious than output environmental damage.[2] At the present time, while there are many papers that address output environmental damage, few papers discuss FDI environmental damage. Therefore, we will concentrate on the effects and the decisions of FDI environmental taxes in such a situation where the output environmental damage is very small due to the predetermined output environmental taxes.[3]

Furthermore, Markusen *et al.* have assumed that FDI and output decisions are made simultaneously in the same stage, and thus adopted a two-stage game model. However, since building plants usually takes considerably longer time than it does to produce goods, we deem FDI decisions and output choices to be made in different stages, which adds a third stage to the two-stage model of Markusen *et al.* Thus, our model is as follows: in the first stage domestic and foreign governments determine their FDI environmental taxes, in the second stage domestic and foreign firms decide their plant sizes (or FDI sizes), and in the third stage these firms choose the

optimal output-export levels.

Finally, Markusen *et al.* have considered only local environmental pollution that does not spill over to other countries. However, in the real world, we face transboundary environmental damage that also affects other countries. In such circumstances, the NIMBY (not in my back yard) problem vanishes, and most countries may suffer from environmental damage that originated in other countries. Hence, we consider transboundary environmental damage.[4]

Thus, we find, among others, that the FDI environmental tax is effective not only as an environmental policy to control firms' FDI environmental damage but also as a strategic policy to plunder the foreign country of its welfare and that, while the phenomenon of NIMBY is often observed, the domestic and foreign countries have a tendency to approve the IMBY (in my back yard) when the environmental damage is transboundary. It is also demonstrated that the FDI environmental taxes imposed on out-flow FDI and in-flow FDI (henceforth, the out-flow FDI environmental tax and the in-flow FDI environmental tax, respectively) have respectively different effects on firms' FDI environmental damage and that both the optimal in-flow and out-flow FDI environmental taxes can be positive or negative under certain reasonable conditions. Furthermore, it is implicitly indicated that when firms' FDI sizes as well as output (export) levels are determined endogenously, changes in the FDI environmental taxes would not have such drastic effects on firms' FDI choices as were indicated by Markusen *et al* (1993 & 1995).

The rest of this paper is organized as follows. In Section 2, taking the issues mentioned above into consideration, a three-stage game model of a duopolistic international industry is established that consists of two (domestic and foreign) multinational firms that both generate transboundary environmental damage in the process of constructing their subsidiary plants by FDI.[5] In Sections 3 and 4, the effects of the FDI environmental taxes on FDI sizes and output-export levels chosen by the domestic and foreign multinationals are analyzed. In section 5, the optimal FDI environmental taxes determined by the domestic and foreign governments are examined. Finally, Section 6 presents concluding remarks.

2. Basic Model and Assumptions

This section establishes a three-stage game model of an international Cournot duopoly that consists of two firms (a domestic firm and a foreign firm) producing homogenous goods and two governments (the domestic government and the foreign government) controlling environmental damage. We suppose that each firm already has a parent plant in its own country and plans to construct a subsidiary plant through FDI in its rival country. This supposition reflects the fact that most multinational firms first establish parent plants in their own countries and later set up subsidiaries in other countries after engaging in exports for some years. Thus, while firms' parent plant sizes are fixed exogenously, their subsidiary plant sizes are determined endogenously.

Further, in order to concentrate on the FDI environmental taxes imposed on the environmental damage resulting from constructing subsidiary plants, we shall exclude the output environmental taxes, under the assumption that the environmental pollution emitted by producing goods had been already reduced to a small enough factor to be ignored before the game begins. Thus, the governments in this paper are concerned solely with the decision regarding FDI environmental taxes.[6]

With respect to the demand side of the industry, the domestic and foreign markets are segregated from each other. Thus, when each firm has a subsidiary plant in its rival country, it has two ways to supply its products to its rival country, i.e., exportation and oversea production. However, we assume that no subsidiary plant exports its products back to its parent country and that each subsidiary sells all its products in its rival country. This assumption may seem to be strange at first sight, but it is not so strange in a homogenous-good model, from a practical point of view.[7] Then, the domestic and foreign inverse demand (twice differentiable) functions are respectively given by $p(Z)=p(X+T^*+Y^*)$ with $p'(Z)<0$ and $p^*(Z^*)=p^*(X^*+T+Y)$ with $p^{*\prime}(Z^*)<0$, where $p(p^*)$ is the domestic (foreign) price, X and T (X^* and T^*) are respectively domestic sales and exports of the domestic (foreign) parent plant, $Y(Y^*)$ is output (= sales) of the domestic (foreign) subsidiary plant, and $Z=X+T^*+Y^*$ ($Z^*=X^*+T+Y$) is total sales in the domestic (foreign) country (henceforth, letters with* denote corresponding variables for the foreign firm or government).

On the other hand, these firms must incur plant construction costs, production costs and export costs. While the firms need not pay construction costs for the existing parent plants, they must incur construction costs for new subsidiary plants. We suppose that plant construction costs of domestic and foreign firms are given by strictly increasing and convex functions, $v(k)$ and $v^*(k^*)$, of their FDI sizes, k and k^*, respectively.[8] We also suppose $v(0)=0$, $v(\infty)=\infty$, $v^*(0)=0$ and $v^*(\infty)=\infty$ for positive FDI sizes at equilibrium.

It is assumed that unit production cost of every plant is independent of its output level, but depends on its plant size. Thus, while unit production costs, C and C^*, of the firms' parent plants are both constant because their plant sixes are both predetermined, unit production costs, c and c^*, of their subsidiary plants are respectively expressed as functions, $c(k)$ and $c^*(k^*)$, of their FDI sizes, k and k^*. Furthermore, we suppose that these functions are both strictly decreasing (due to scale merits) and convex (due to decreasing scale merits). The firms' export costs are composed of market exploitation costs, transportation costs, sales costs and official transaction costs. Then, these are given, respectively, by the strictly increasing functions, $G(T)$ and $G^*(T^*)$, of firms' exports, T and T^*, respectively.

Finally, as political instruments to control the firms' FDI environmental damage, the domestic and foreign governments impose FDI environmental taxes based on their FDI sizes, k and k^*, respectively. This is why the firm's FDI environmental dam-

age caused by its subsidiary plant construction depends on its FDI size. However, since the domestic and foreign FDI result in there being different environmental damage on the respective countries, the governments would impose different FDI environmental taxes on the domestic and foreign FDI, respectively.

Now, we denote the unit domestic (foreign) FDI environmental tax imposed on the domestic (foreign) FDI by $t(t^*)$ and the unit domestic (foreign) FDI environmental tax imposed on the foreign (domestic) FDI by $\tau(\tau^*)$. Then, considering that while the domestic FDI is regarded as out-flow (in-flow) FDI by the domestic (foreign) country, the foreign FDI is taken as in-flow (out-flow) FDI by the domestic (foreign) country, we call $t(t^*)$ the domestic (foreign) out-flow FDI environmental tax and $\tau(\tau^*)$ the domestic (foreign) in-flow FDI environmental tax, respectively.[9]

Now, under the assumptions mentioned above, profits of the domestic and foreign firms, Π and Π^*, are respectively given by

$$\begin{aligned}\Pi=&\{p(Z)X+p^*(Z^*)T\\&-C(X+T)-G(T)\}\\&+\{p^*(Z^*)Y-c(k)Y\\&-v(k)\}-(t+\tau^*)k,\end{aligned}\tag{1}$$

$$\begin{aligned}\Pi^*=&\{p^*(Z^*)X^*+p(Z)T^*\\&-C^*(X^*+T^*)-G^*(T^*)\}\\&+\{p(Z)Y^*-c^*(k^*)Y^*\\&-v^*(k^*)\}-(t^*+\tau)k^*.\end{aligned}\tag{2}$$

In (1) and (2), the first and second terms braced by { } are profits of the domestic (foreign) parent and subsidiary plants respectively, and the third terms are the total FDI environmental tax payment, respectively. Of course, a negative FDI environmental tax means a FDI environmental subsidy.

Finally, suppose that domestic and foreign FDI environmental damage in the domestic country are expressed respectively by strictly increasing and convex functions, $\phi(k)$ and $\psi(k^*)$, of the domestic and foreign FDI sizes. Then, the domestic economic welfare, W is given by

$$\begin{aligned}W=&\{\int_0^Z p(s)ds-p(Z)Z\}+\Pi\\&+tk+\tau k^*-\phi(k)-\psi(k^*),\end{aligned}\tag{3}$$

where $\{\int_0^Z p(s)ds-p(Z)Z\}$ is the domestic consumer's surplus, Π is the domestic producer's surplus, $tk+\tau k^*$ is the domestic government's surplus, and $\phi(k)$ and $\psi(k^*)$ are the domestic FDI environmental damages suffered from the domestic and foreign FDI respectively. Similarly, the foreign economic welfare, W^*, is defined as

$$\begin{aligned}W^*=&\{\int_0^{Z^*} p^*(\theta)d\theta-p^*(Z^*)Z^*\}+\Pi^*\\&+t^*k^*+\tau^*k-\phi^*(k^*)-\psi^*(k).\end{aligned}\tag{4}$$

The firms choose (X, T, Y) and (X^*, T^*, Y^*) in the third stage and k and k^* in the second stage so as to maximize their profits defined by (1) and (2), respectively. Further, the governments respectively determine their FDI environmental taxes (t, τ) and (t^*, τ^*) so as to maximize their welfare expressed as (3) and (4) in the first stage. In what follows, we will solve these problems inversely from the third stage to the first stage by using backward

induction.

3. Firms' Output-Export Choices in the Third Stage

Assuming the inner solutions (since the corner solutions are trivial)[10] and the second-order conditions,[11] the domestic and foreign firms' conditions for maximizing the profits are respectively given by

$$p(Z)+p'(Z)X-C=0, \quad (5)$$

$$p^*(Z^*)+p^{*\prime}(Z^*)(T+Y) -G'(T)-C=0, \quad (6)$$

$$p^*(Z)+p^{*\prime}(Z^*)(T+Y)-c(k)=0, \quad (7)$$

and

$$p^*(Z^*)+p^{*\prime}(Z^*)X^*-C^*=0, \quad (8)$$

$$p(Z)+p'(Z)(T^*+Y^*) -G^{*\prime}(T^*)-C^*=0, \quad (9)$$

$$p(Z)+p'(Z)(T^*+Y^*)-c^*(k^*)=0, \quad (10)$$

Among the first-order conditions, (5) and (8) are the output reaction functions between the firms' parent plants, (6) and (9) are the export reaction functions between the firms' parent plants, and (7) and (10) are the output reaction functions between the firms' subsidiary plants. Whether these reaction functions are depicted as downward or upward sloping curves depends on whether the firms' products are strategically substitutive or complementary. However, it is reasonable to regard the firms' products as being strategically substitutive for each other when they are homogenous. Then, the reaction curves are all downward sloping and the demand functions satisfy the following conditions: $p'(Z)+p''(Z)X<0$, $p^{*\prime}(Z^*)+p^{*\prime\prime}(Z^*)(T+Y)<0$, $p^{*\prime}(Z^*)+p^{*\prime\prime}(Z^*)X^*<0$ and $p'(Z)+p''(Z)(T^*+Y^*)<0$.

The Nash-Cournot industry equilibrium of the third stage is given by a vector of (X, T, Y, X^*, T^*, Y^*) that satisfies the equation system of (5)-(10). However, it is easily shown that, while the equilibrium levels of X, T^* and Y^* are derived from (5), (9) and (10), those of X^*, T and Y are obtained by solving (6), (7) and (8). Then, it is shown that the industry equilibrium in the third stage is locally stable (see the Routh-Hurvitz Theorem).

As has been described, while firms' FDI levels, k and k^*, are parameters in the third stage, they are firms' control variables in the second stage. Therefore, it is of interest to derive the effects of changes in k and k^* on the firms' output-export choices, since those effects explain the relationships between firms' decisions in the second and third stages. Hence, differentiating totally all of (5)-(10) and taking account of features of the demand functions and the cost functions, we obtain

$$\frac{\partial T}{\partial k}<0, \frac{\partial Y}{\partial k}>0, \frac{\partial X^*}{\partial k}<0, \quad \frac{\partial T^*}{\partial k}=\frac{\partial Y^*}{\partial k}=\frac{\partial X}{\partial k}=0, \quad (11)$$

$$\frac{\partial T^*}{\partial k^*}<0, \frac{\partial Y^*}{\partial k^*}>0, \frac{\partial X}{\partial k^*}<0, \quad \frac{\partial T}{\partial k^*}=\frac{\partial Y}{\partial k^*}=\frac{\partial X^*}{\partial k^*}=0. \quad (12)$$

Then, (11) and (12) combine to present

Proposition 1. *A rise in the domestic (foreign) firm's FDI increases output of the domestic (foreign) subsidiary plant, but reduces both exports of the domestic (foreign) parent plant and output of the*

foreign (domestic) parent plant, and vice versa. However, it has no effect on output of the domestic (foreign) parent plant, exports of the foreign (domestic) parent plant or output of the foreign (domestic) subsidiary plant.

Furthermore, from (11) one gets

$$\frac{\partial(T+Y)}{\partial k}>0,\ \frac{\partial(T+X+Y)}{\partial k}>0,\ \frac{\partial Z^*}{\partial k}>0,$$
$$\frac{\partial(T+X)}{\partial k}<0,\ \frac{\partial(T^*+X^*)}{\partial k}<0,\ \frac{\partial Z}{\partial k}=0,$$
$$\frac{\partial(T^*+X^*+Y^*)}{\partial k}<0 \text{ and } \frac{\partial(T^*+Y^*)}{\partial k}=0.$$

Since the effects of a change in the foreign FDI are symmetrical to those of a change in the domestic FDI, as is clear from (11) and (12), similar results hold with respect to the effects of a change in the foreign FDI. Thus, from (12) we can present

$$\frac{\partial(T^*+Y^*)}{\partial k^*}>0,\ \frac{\partial Z}{\partial k^*}>0,$$
$$\frac{\partial(T^*+X^*+Y^*)}{\partial k^*}>0,\ \frac{\partial(T^*+X^*)}{\partial k^*}<0,$$
$$\frac{\partial(T+X)}{\partial k^*}<0,\ \frac{\partial(T+X+Y)}{\partial k^*}<0,$$
$$\frac{\partial Z^*}{\partial k^*}=0 \text{ and } \frac{\partial(T+Y)}{\partial k^*}=0.$$

All these results combine to present

Corollary 1. *A rise in the domestic (foreign) firm's FDI raises the domestic (foreign) firm's total overseas sales, the domestic (foreign) firm's total output and foreign (domestic) consumption, but it reduces output of the domestic (foreign) parent plant, output of the foreign (domestic) parent plant and the foreign (domestic) firm's total output, and vice versa. However, a change in the domestic (foreign) firm's FDI has no effect on the domestic (foreign) consumption or the foreign (domestic) firm's total overseas sales.*

While $\frac{\partial Z^*}{\partial k}>0$ and $\frac{\partial Z}{\partial k^*}>0$ imply that the FDI improves its rival country's consumption, $\frac{\partial Z}{\partial k}=\frac{\partial Z^*}{\partial k^*}=0$ show that the FDI does not change its own country's consumption. On the other hand, $\frac{\partial(Y+T^*+X^*)}{\partial k}>0$ and $\frac{\partial(Y^*+T+X)}{\partial k^*}>0$ mean that the FDI increases output level in the rival country, but $\frac{\partial(Y^*+T+X)}{\partial k}<0$ and $\frac{\partial(Y+T^*+X^*)}{\partial k^*}<0$ demonstrate that the FDI reduces output level in its own country. Therefore, the FDI is generally welcomed by both consumers and the firm in its rival country, but not welcomed by the firm in its own country, *ceteris paribus*.

Finally, Proposition 1 and Corollary 1 combine to show that, if the FDI levels are controlled by changing the FDI environmental taxes, the governments can utilize those taxes as tools to implement strategic policies for managing firms' market shares and revenues. Hence, in the next section, we will examine whether the governments can control the firms' FDI levels by FDI environmental taxes.

4. Firms' FDI Decisions in the Second Stage

In the second stage, the Cournot domestic and foreign firms non-cooperatively

choose their FDI levels, k and k^*, so as to maximize their profits, given all the FDI environmental taxes, the optimal output-export levels, the rival's FDI level and the parameters in (1) and (2), respectively. Thus, taking into consideration that the conditions of (5)-(10) are always satisfied in industry equilibrium of the third stage and that the plant construction cost functions ensure positive levels of k and k^*, the first-order conditions in the second stage are given by

$$p^{*\prime}(Z^*)\frac{\partial X^*}{\partial k}(T+Y)-c'(k)Y - v'(k)-(t+\tau^*)=0, \quad (13)$$

$$p'(Z)\frac{\partial X}{\partial k^*}(T^*+Y^*)-c^{*\prime}(k^*)Y^* - v^{*\prime}(k^*)-(t^*+\tau)=0. \quad (14)$$

The second-order conditions are $\frac{\partial^2\Pi}{\partial k^2}<0$ and $\frac{\partial^2\Pi^*}{\partial k^{*2}}<0$, respectively.[12]

The Cournot-Nash industry equilibrium in the second stage is given by k and k^* satisfying (13) and (14) simultaneously. Since $\frac{\partial^2\Pi}{\partial k^*\partial k}=0$ and $\frac{\partial^2\Pi^*}{\partial k\partial k^*}=0$ hold at the industry equilibrium of the second stage, these conditions and the firms' second-order conditions ensure that the equilibrium is locally stable (see the Routh-Hurvitz theorem).

As is shown by (13) and (14), both the firms' optimal FDI levels, k and k^*, at the industry equilibrium in the second stage depend on the FDI environmental taxes, t, t^*, τ and τ^*, determined by the domestic and foreign governments in the first stage. Since the FDI environmental damage is related positively to firms' FDI levels, the signs of the effects of changes in FDI environmental taxes on FDI environmental damage equal the effects of changes in the FDI environmental taxes on firms' FDI levels. Hence, let us derive the latter effects.

Differentiating totally (13) and (14), we can obtain the effects of changes in t, t^*, τ and τ^*, on the optimal levels of k and k^* at the industry equilibrium:

$$\frac{\partial k^*}{\partial t}=\frac{\partial k^*}{\partial \tau^*}=0, \quad \frac{\partial k}{\partial t}=\frac{\partial k}{\partial \tau^*}=\frac{1}{\left(\frac{\partial^2\Pi}{\partial k^2}\right)}<0, \quad (15)$$

$$\frac{\partial k}{\partial t^*}=\frac{\partial k}{\partial \tau}=0, \quad \frac{\partial k^*}{\partial t^*}=\frac{\partial k^*}{\partial \tau}=\frac{1}{\left(\frac{\partial^2\Pi^*}{\partial k^{*2}}\right)}<0. \quad (16)$$

Clearly, both the domestic out-flow FDI environmental tax and the foreign in-flow FDI environmental tax have negative effects on the domestic firm's FDI, but do not affect the foreign firm's FDI. By contrast, both the foreign out-flow FDI environmental tax and the domestic in-flow FDI environmental tax have negative effects on the foreign firm's FDI, but do not change the domestic firm's FDI. Therefore, taking into consideration that the FDI environmental damage is related positively to the firm's FDI level, (15) and (16) combine to present the following proposition:

Proposition 2. *Both the domestic (foreign) out-flow FDI environmental tax and the foreign (domestic) in-flow FDI environmental tax have negative effects on the FDI*

environmental damage of the domestic (foreign) subsidiary plant. However, both the foreign (domestic) out-flow FDI environmental tax and the domestic (foreign) in-flow FDI environmental tax have no effects on the FDI environmental damage of the domestic (foreign) subsidiary plant.

It is obvious from this proposition that even if a single FDI environmental tax policy is not effective, mixed FDI environmental tax policies become effective as the policies for controlling the firms' FDI environmental damage. For example, neither the domestic government nor the foreign government can control the rival firm's FDI scale (FDI environmental damage) by changing only its out-flow FDI environmental tax. They can, however, manage both the domestic and foreign firms' FDI levels (FDI environmental damage) by mixing appropriately their out-flow and in-low FDI environmental taxes. Moreover, this proposition also demonstrates, together with Proposition 1, that the governments can use FDI environmental taxes as tools for implementing strategic policies.

It should be emphasized at this point that since the firms in this model can arrange their FDI levels smoothly when the governments change the FDI environmental taxes, environmental taxes do not have such drastic effects on firms' FDI levels as was indicated by Markusen *et al.* (1992 and 1995). This stems from the difference in assumptions: while they assumed exogenous constant FDI sizes, we suppose that firms' FDI sizes are determined endogenously. When the firms' FDI sizes are endogenous variables, the construction costs of subsidiary plants are also decided endogenously. Thus, firms can mitigate a drastic change in their plant choice that stems from the existence of large fixed (sunk) costs by adjusting the FDI sizes smoothly.

5. Governments' Environmental Tax Decisions in the First Stage

The domestic and foreign governments decide non-cooperatively their FDI environmental taxes, (t, τ) and (t^*, τ^*), so as to maximize their economic welfare defined as (3) and (4). Then, supposing that the governments act also as Cournot-followers and that (5)-(16) hold at equilibrium, the first-order conditions for maximizing the domestic and foreign welfare are given by

$$t + p^{*\prime}(Z^*)(T+Y)\frac{\partial X^*}{\partial k} - \phi'(k) = 0, \quad (16)$$

$$-p'(Z)Z\frac{\partial Z}{\partial k^*} + p^{*\prime}(Z^*)(T+Y)\frac{\partial (T^*+Y^*)}{\partial k^*} + \frac{k^*}{\dfrac{\partial k^*}{\partial \tau}} + \tau - \psi'(k^*) = 0 \quad (17)$$

$$t^* + p'(Z)(T^*+Y^*)\frac{\partial X}{\partial k^*} - \phi^{*\prime}(k^*) = 0, \quad (18)$$

$$-p^{*\prime}(Z^*)Z^*\frac{\partial Z^*}{\partial k} + p'(Z)(T^*+Y^*)\frac{\partial (T+Y)}{\partial k} + \frac{k}{\dfrac{\partial k}{\partial \tau^*}} + \tau^* - \phi^{*\prime}(k) = 0. \quad (19)$$

Since the optimal domestic and foreign out-flow and in-flow FDI environmental taxes, denoted by t^e, τ^e, t^{*e}, and τ^{*e}, satisfy equations (16)-(19), the signs of the

taxes may be examined by using these equations.[13] Thus, we shall discuss them in order.

(16) gives the optimal domestic out-flow FDI environmental tax, t^e, as

$$t^e = -p^{*\prime}(Z^*)(T+Y)\frac{\partial X^*}{\partial k} + \phi'(k). \quad (20)$$

Considering Propositions 1 and 2, the demand function and the environmental damage functions, we can show that while the first term in the right hand side of (20) is negative, the second (last) term is positive. Apparently, the optimal domestic in-flow FDI environmental tax is not equal to the marginal environmental damage, $\phi'(k)$, of the domestic out-flow FDI, it is rather smaller than the marginal environmental damage, $\phi'(k)$, of the domestic out-flow FDI.

If the FDI environmental damage is not local, the second term disappears, and thus the optimal domestic out-flow FDI environmental tax becomes equal to the first term which is negative definitely. This means that the domestic government gives a FDI environmental subsidy to the out-flow FDI of the domestic firm. However, this is not a strange result, since the NIMBY phenomenon occurs in such a case. The domestic government tries to protect its own country from the FDI environmental damage by promoting its domestic out-flow FDI with a subsidy.

However, when the FDI environmental damage is global, the second term would not disappear. Therefore, when the positive first term in the right side of (20) is larger than the absolute value of the negative second term, the optimal domestic out-flow FDI environmental tax becomes positive, and then the NIMBY problem disappears. This is why, even if the domestic government successfully raises its subsidiary plant size by a negative out-flow FDI environmental tax (= a positive out-flow FDI environmental subsidy), the domestic country cannot be relieved of its damage completely.

When the domestic government faces global FDI environmental damage, it must decide its optimal out-flow FDI environmental tax by considering both the terms included in the right-hand side of (20). Consequently, the optimal domestic out-flow FDI environmental tax can be positive or negative as the second term in the right-hand side of (20) is larger or smaller than the absolute value of the first term in the right-hand side of (20). Then, it must be noted that even if the domestic out-flow FDI causes the FDI environmental damage to the domestic country, the optimal domestic out-flow FDI environmental tax is not always positive.

Next, considering (17), the optimal domestic in-flow FDI environmental tax, τ^e, is expressed as

$$\tau^e = p'(Z)Z\frac{\partial Z}{\partial k^*} - p^{*\prime}(Z^*)(T+Y)\frac{\partial(T^*+Y^*)}{\partial k^*} - \frac{k^*}{\dfrac{\partial k^*}{\partial \tau}} + \psi'(k^*). \quad (21)$$

Then, while the first term on the right-hand side of (21) is negative, the other terms are all positive. Hence, the optimal domestic in-flow FDI environmental tax

can be positive or negative as the sum of the positive terms is bigger or smaller than the absolute value of the negative first term. This is true even if the FDI environmental damage is local, since only the last term disappears.

When the domestic in-flow FDI environmental tax is positive, the domestic government restricts in-flow FDI from the foreign country. Then, the NIMBY phenomena might be observed. On the other hand, when the domestic in-flow FDI environmental tax is negative, the domestic government tries to induce in-flow FDI from the foreign country. Thus, the NIMBY problem vanishes, and the IMBY phenomenon is observed.

Similarly, the optimal foreign out-flow and in-flow FDI environmental taxes, t^{*e} and τ^{*e}, are obtained from (18) and (19), respectively. However, since features of these taxes are quite symmetrical to those of the optimal domestic out-flow and in-flow FDI environmental taxes given by (20) and (21). So, here we omit them.

Now, the above arguments are paraphrased as

Proposition 3: (*i*) *While the optimal domestic* (*foreign*) *out-flow FDI environmental tax is negative* (*the NIMBY phenomena occurs*) *if the FDI environmental damage is local, it can be positive* (*the NIMBY problem may disappear and the IMBY phenomena may appear*) *when the damage is global. On the other hand,* (*ii*) *the optimal domestic* (*foreign*) *in-flow FDI environmental tax can be positive or negative* (*either the NIMBY or the IMBY may be observed*) *regardless of whether the environmental damages are local or global.*

6. Concluding Remarks

In this paper, we first established a three-stage game model of an international Cournot industry consisting of two multinational firms (a domestic firm and a foreign firm) that generate both FDI environmental damage and two governments (the domestic and foreign countries) that impose both the FDI environmental taxes on firms' environmental damage, and then examined about the FDI environmental taxes. Though several interesting results are found, they are summarized as propositions in previous sections. Therefore, we do not repeat them here, but refer to some of their theoretical and/or practical implications.

It is obvious from Propositions 2 and 3 that FDI environmental taxes are used, not only as environmental policies, but also as strategic FDI or trade policies. Thus, though FDI environmental taxes are political instruments to control FDI environmental damage, they might be used to manage firms' FDI or export. However, this would be regarded as abuse of FDI environmental taxes since they would not then be used for their original purpose.

It is also demonstrated that IMBY cases can occur when the FDI environmental damage is global. This is why the government's objective is not to minimize its environmental damage, but to maximize its social welfare. Taking account of all the effects of the FDI environmental tax on the sum of the consumer's surplus, the producer's surplus, the government's sur-

plus and the environmental damages, the government chooses the FDI environmental tax. Consequently, some governments would decide FDI environmental taxes that induce in-flow FDI that scatter the environmental damage in their back yards if they improve their welfare as a whole. Thus, it is not appropriate to assert that the FDI environmental taxes should always be positive.

Furthermore, it might be shown that FDI environmental taxes would not have such a drastic effect on the firms' plant choices as was indicated by Markusen, *et al*. (1993 and 1995). When the firms can endogenously choose their subsidiary plant sizes (or FDI sizes), they can control plant construction costs in response to the FDI environmental taxes. Hence, in such a case the firms can adjust their subsidiary plant sizes more smoothly than in the case supposed by Markusen, *et al*.

There are several ways to extend the present model. By modifying some of the assumptions of homogenous goods, constant parent plants, Cournot duopoly, three-stage game and so on, more generalized propositions might be proposed.

Footnotes

1 For example, when Toyota plans to build a subsidiary plant in China, it might consider the difference in environmental taxes between Japan and China, among other things. However, no such difference will, in and of itself, induce Toyota to move its parent plant from Japan to China. Yet, Markusen *et al*. assumed 'footloose' firms that easily shift even parent plants. Motta and Thisse (1994) modified the assumption of 'footloose' firms and found that a change in the environmental tax does not cause such a drastic change in plant location as suggested by Markusen *et al*. Moreover, Hoel (1997) presented a model in which firms endogenously choose plant location, though the firms are not multinationals.

2 Many Japanese companies used to exploit the sea shallows and/or beautiful green hills to build manufacturing plants and/or leisure facilities. The environmental damage caused by constructing such plants and facilities will continue to have an adverse effect on the Earth even after output environmental damage has been dealt with, since it has altered nature and ecosystems throughout Japan. A similar situation will also occur in many developing countries.

3 At the present time when the implementation of output environmental taxes is still of great concern, industries to which our model is suitable might be still few. However, industries that fit our model will increase in the future, when output environmental damage is improved due to the long-term imposition of output environmental taxes. In such a case that output environmental damage is than a permissible level, output environmental tax may be very low even if it is positive. The role of economics is to analyze not only past and present economic issues, but also future ones.

4 There are many models considering transboundary pollutions. See Copeland and Taylor (1995) and Unteroberdoerster (1995), for example.

5 This model depends on Motta and Thisse (1994), Brander and Krugman (1983), Brander and Spencer (1985 and 1987) and Hoel (1997). Following Motta and Thisse (1994), we assume that both firms have the parent plants in their countries when the game begins.

6 As far as I know, there exist no papers that analyze both FDI environmental damage and taxes. Though we exclude output environmental damage and taxes in this paper in order to highlight FDI environmental damage and taxes, it is not so difficult to introduce all of them into the model.

7 Baldwin and Ottaviano (2002), Belderbos and Sleuwaegen (1996) and Blonigen (2001) have found that many subsidiaries (except for screwdriver plants) would not export their products to the mother countries where the parent firms produce homogenous goods.

8 The strictly increasing and convex plant construction cost function and the constant unit production costs are true under some plausible conditions. In this paper all the functions are assumed to be twice differentiable at least.

9 We assume that the domestic (foreign) government imposes out-flow and in-flow FDI environmental taxes on the domestic and foreign firms' FDI sizes, respectively.

10 It is not difficult to show the plausibility of the inner solution.

11 The second-order condition of the domestic firm for profit maximization is given by $D_{11}<0$, $D_{22}<0$, $D_{33}<0$, $D_{11}D_{22}>0$, $D_{11}D_{33}>0$, $D_{22}D_{33}>0$, $D_{23}D_{32}>0$, and $D_{11}(D_{22}D_{33}-D_{23}D_{32})<0$, adopting notations of $D_{11}=p''(Z)X+2p'(Z)$, $D_{22}=p^{*\prime\prime}(Z^*)(T+Y)+2p^{*\prime}(Z^*)-G'(T)$ and $D_{23}=D_{32}=D_{33}=p^{*\prime\prime}(Z^*)(T+Y)+2p^{*\prime}(Z^*)$.

12 In (13), the conditions of $\lim_{k=0}v'(k)=0$ and $\lim_{k=\infty}v'(k)=\infty$ exclude a corner solution of $k=0$, and the same reasoning is applied to (14).

13 It is assumed that the second-order conditions for maximizing the domestic welfare are satisfied in the neighborhood of the equilibrium.

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