FDI Subsidies When Both Plant Location and Size are Endogenous under Capital Constraints *

by Yasunori Ishii **

This paper exploits a simple three-stage reciprocal market game model of an international Cournot duopoly, consisting of domestic and foreign multinational firms to examine FDI subsidy policies of domestic and foreign governments. The governments decide FDI subsidies in the first stage. Then, the firms choose endogenously both plant locations and sizes under capital constraints in the second stage and output-export levels in the third stage. This paper finds that while the FDI subsidies have definite effects on firms' FDI levels, they do not induce drastic changes regarding firms' plant locations and that the optimal FDI subsidies depend on features of firms' reaction functions.

1. Introduction

Recently, the number of studies on international duopoly (or oligopoly) has been increasing. One of their main purposes is to investigate whether governments can use certain economic policies, such as tariffs, export subsidies and so on, as the basis for economic strategies to deprive foreign countries of their economic welfare when a few big firms compete in imperfectly competitive international markets.

Many papers, initiated by Brander and Krugman (1983) and Brander and Spencer (1984 and 1985), have established various types of imperfectly competitive trade model in which only uninational firms that engage in no overseas production compete against each other for international market shares by exporting goods and have shown that trade policies, such as tariffs and export subsidies, are generally effective as economic strategies. By contrast, Janeba (1998) and Ishii (2001) have exploited duopoly models where multinational firms with subsidiaries in foreign countries compete with each other for market shares by overseas production as well as exports and have demonstrated that tariffs remain effective but export subsidies lose their effectiveness.

Though the proposition presented by Janeba (1998) and Ishii (2001) is useful and of interest, both their models assume

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implicitly that plant sizes of multinational firms are exogenously given as constant. However, when firms act as multinational firms in the present world they determine endogenously both plant sizes and locations. Furthermore, they do not consider policies to control plant sizes and locations of multinational firms. Therefore, the proposition shown by Janeba (1998) and Ishii (2001) is restrictive from a political, as well as a descriptive, point of view.

As the number of imperfectly competitive international markets that consist of a few big multinational firms that have subsidiary plants in multiple countries by foreign direct investment (henceforth, FDI) has increased, so has the likelihood that governments adopt policies for controlling firms' FDI (henceforth, FDI policies) with strategic economic aims. Indeed, multinational firms provide their products for foreign countries, not only by exporting from the parent plants in their domestic countries, but also by supplying from their subsidiary plants in foreign countries. Therefore, it is of great significance and utility to establish an international duopoly model that considers firms' FDI or plant choices and to investigate the effects of FDI policies on firms' FDI sizes and optimal levels of FDI policies.

Although their purpose is different from that of this paper, Markusen *et al*. (1993 and 1995) presented a model in which firms endogenously determine their plant locations and have shown that governmental policies (environmental taxes in their model) cause drastic changes in firms' plant locations. Then, in order to highlight their result they assumed that firms can easily move all production plants anywhere in the world (that is, firms are 'footloose'), that firms' plant sizes are exogenously determined as constant, and that firms are free from capital constraints. However, these assumptions are not plausible in all international industries.

In some real-world international industries, firms that already have production plants in their countries of origin (henceforth, parent plants) do not move their parent plant across countries as easily as they do their plants in other countries (henceforth, subsidiary plants), that is, they are not 'footloose'. It is also true that when firms intend to construct new production plants by using FDI, they can choose their plant sizes or FDI sizes as well as their locations endogenously. Furthermore, firms cannot expand their plant sizes or FDI sizes freely, because the available amount of capital for FDI is bounded by credit constraints and/or technological constraints. Thus, firms in the actual world have capital constraints with an upper limit. In this paper, we first establish a more generalized international duopoly model that considers these futures and constraints. Then, we analyze the effectiveness and optimal levels of FDI subsidies, as strategic FDI policies, using such a model.[1]

In order to investigate the issues mentioned above, this paper will expand upon the model exploited by Markusen *et al*. to include (i) endogenous choices of plant size and location by duopolistic multinational firms under capital constraints and (ii) optimal FDI subsidy decisions by governments.[2] Therefore, though the framework of the present model seems to be similar to that of the Markusen *et al*.

model, there exists an essential difference between the two.

The Markusen *et al*. model is a two-stage game model, since they implicitly assumed that firms' decisions of plant location and output are made simultaneously in the same stage. However, this assumption is very curious. Since plant construction takes considerable time in the actual world, it is quite plausible to regard plant decisions and output-export choices as being made in different stages, which introduces one more stage into the Markusen *et al*. model.[3] Then, the present model becomes a three-stage game model: that is, the governments determine the FDI subsidies in the first stage, and then the firms decide their plant locations and sizes under capital constraints in the second stage and choose the optimal outputs and exports in the third stage. As a result, this paper finds, among other things, that FDI subsidies are also effective as strategic political instruments and that they have generally positive effects on firms' FDI sizes. It also demonstrates that the optimal FDI subsidies are not always positive and that FDI subsidies do not have such drastic effects on the firms' plant choices as are indicated by Markusen, *et al*. (1993 and 1995).

The rest of this paper is organized as follows. Section 2 establishes a generalized model of an international Cournot duopoly, as was explained above. Section 3 analyzes the firms' output-export choices. Section 4 examines the firms' FDI decisions. Section 5 discusses the optimal FDI subsidies. Section 6 presents concluding remarks.

2. Assumptions and Basic Model

This section will establish a very simple generalized model of an international Cournot duopoly consisting of a domestic firm and a foreign firm. The present model supposes an international Cournot duopoly, in which both firms have already parent plants of fixed sizes, A and A^*, that produce homogenous goods in their original countries, and intend to expand the parent plants by additional domestic investment (henceforth, ADI), K and K^*, and/or to build new subsidiary plants producing the same goods by FDI, k and k^*, in their rival countries, respectively. (Henceforth, the notations with asterisks, *, express the foreign variables that correspond to the domestic variables).

The above reflects the fact that most multinational firms in the actual economy first establish parent plants and later set up subsidiaries, after having engaged in exports for several years. Thus, firms' parent and subsidiary plant sizes are both endogenously determined by choosing ADI and FDI, respectively. When firms choose zero levels of FDI, they are still uninational firms, but when they decide to build their subsidiary plants by choosing positive FDI levels, they become multinational firms. Moreover, it is clear that if $A = 0$ and $A^* = 0$ hold, the present model reduces to that of Markusen *et al*.. Therefore, the present model includes that of Markusen *et al*. as a special case.

Capital constraints

We consider capital constraints. One

important and oft-observed factor in big multinational firms that face such capital constraints is technological in nature. When capital equipment demanded by the firms in question has a particular technical specification and/or is produced by a few small firms that cannot adopt mass-production systems, big multinational firms might have difficulty in obtaining sufficient capital equipment to carry out their ADI and FDI plans. Furthermore, even big multinational firms cannot always gather sufficient funds to achieve their plant choices. In such cases the home and foreign firms face capital constraints, respectively. This paper analyzes such a case where firms' capital constraints are bounded:

$$K+k=\bar{K} \text{ and } K^*+k^*=\bar{K}^*,$$

where $\bar{K}$ and $\bar{K}^*$ are, respectively, the upper limits of (real) capital that are available for firms' ADI and FDI.

Demand functions

Suppose that the domestic and foreign markets are segregated from each other. While the domestic and foreign firms supply goods produced by their parent plants to both countries, they sell goods produced by their subsidiary plants only in the rival country where their respective subsidiary plants are constructed. Then, both the domestic and foreign firms have two routes to supply their goods to the rival country: exports and overseas production. This assumption that the subsidiaries do not export their products back to the parent countries may seem to be strict at first sight, but it is not so in a homogenous good model, with respect to both the real-world situation and the theoretical standpoint.[4]

Thus, the domestic and foreign inverse demand functions (assumed to be twice differentiable) are given respectively 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 and p^* are, respectively, the domestic and foreign prices, X and T (X^* and T^*) are respectively the home sale and export of the domestic (foreign) parent plant, and $Y(Y^*)$ is the output (= sale) of the domestic (foreign) subsidiary plant.

Cost functions

When firms plan to be multinationals they consider three different categories of cost: plant construction, production and export. Therefore, it is necessary to examine these cost functions in some detail.

Plant expansion and construction costs:

Since the domestic and foreign firms plan to expand parent plants by ADI and to construct subsidiary plants by FDI, they must incur expansion costs, V and V^*, for parent plants and construction costs, v and v^*, for their subsidiary plants, respectively. It is supposed that these costs are all expressed by twice differentiable and strictly increasing-convex functions of their ADI and FDI sizes, respectively. Then, while firms' cost functions for the expansion of the parent plants are given respectively by $V(K)$ (with $V'(K)>0$ and $V''(K)>0$ for $K>0$) and $V^*(K^*)$ (with $V^{*\prime}(K^*)>0$ and $V^{*\prime\prime}(K^*)>0$ for $K^*>0$), the cost functions for construction of their subsidiary plants are given respectively by $v(k)$ (with $v'(k)>0$ and

$v''(k) > 0$ for $k > 0$) and $v^*(k^*)$ (with $v^{*\prime}(k^*) > 0$ and $v^{*\prime\prime}(k^*) > 0$ for $k^* > 0$). It is clear that, while these plant expansion and construction costs are fixed in the third stage when the firms choose their optimal output-export levels, they are variable in the second stage when the firms decide their optimal ADI and FDI sizes.

Production costs: While positive ADI levels expand sizes of firms' parent plants, positive FDI levels determine the sizes of firms' subsidiary plants. Hence, all unit production costs, C and C^*, of the firms' parent plants and unit production costs, c and c^*, of the firms' subsidiary plants are regarded as decreasing with their ADI, K and K^*, and their FDI, k and k^*, respectively (due to scale merits, for example). Thus, all unit production costs of these plants, C, C^*, c and c^* are given by (twice differentiable) functions such as $C(K)$ with $C'(K) < 0$, $C^*(K^*)$ with $C^{*\prime}(K^*) < 0$, $c'(k) < 0$ and $c^*(k^*)$ with $c^{*\prime}(k^*) < 0$. Furthermore, $C(K)$, $C^*(K^*)$, $c(k)$ and $c^*(k^*)$ are all regarded as strictly convex, i.e., $C''(K) > 0$, $K^{*\prime\prime}(K^*) > 0$, $c''(k) > 0$ and $c^{*\prime\prime}(k^*) > 0$, since the scale merit decreases with plant size.[5]

Export costs: Export costs of the domestic and foreign firms consist of transportation costs, sale costs and official transaction costs. In order to increase exports, the firms have to explore new markets and send their goods to more distant areas in their rivals' counties. Therefore, export costs of the domestic and foreign firms are respectively expressed as (twice differentiable) export cost functions, $G(T)$ and $G^*(T^*)$, whose marginal costs are strictly positive, i.e., $G'(T) > 0$ and $G^{*\prime}(T^*) > 0$, and increase with exports, i.e., $G''(T) > 0$ and $G^{*\prime\prime}(T^*) > 0$, for some of, but not the entire, positive range of exports.[6]

Political instruments

Various instruments may be used to control firms' FDI flows (ADI flows), but the present model concentrates only on FDI (ADI) subsidies, because FDI (ADI) subsidies are generally regarded as more useful and appropriate than any other political instrument for controlling firms' FDI or ADI flows. Of course, though it is not so difficult to incorporate explicitly some other policy instruments, such as tariffs, export subsidies and so on, into the model, the effects of these policies on FDI flows have already received much attention. It is assumed that the domestic and foreign governments provide, respectively, per-unit FDI subsidies, s and s^*, for out-flow FDI and per-unit FDI subsidies, s_k and s_k^*, for in-flow FDI. Of course, negative FDI subsidies imply FDI taxes.

However, as is clear from the definitions, the domestic (foreign) firm's FDI is regarded as the out-flow FDI by the domestic (foreign) country and as the in-flow FDI by the foreign (domestic) country. So, let s, s_k, s^* and s_k^* be, respectively, the domestic out-flow FDI subsidy, the domestic in-flow FDI subsidy, the foreign out-flow FDI subsidy, and the foreign in-flow FDI subsidy. Since the domestic and foreign governments choose their FDI subsidies so as to maximize their welfare in the first stage and keep them constant thereafter, all the FDI subsidies, s, s^*, s_k and s_k^*, are parameters for the domestic and foreign firms in the second and third stages.

Firms' profits

Under the conditions explained above, profits of the domestic and foreign firms denoted by Π and Π^* are defined respectively as

$$\Pi = \{p(Z)X + p^*(Z^*)T - C(\bar{K}-k)(X+T) - V(\bar{K}-k) - G(T)\} + \{p^*(Z^*)Y - c(k)Y - v(k)\} + (s+s_k^*)k, \tag{1}$$

and

$$\Pi^* = \{p^*(Z^*)X^* + p(Z)T^* - C^*(\bar{K}^*-k^*)(X^*+T^*) - V^*(\bar{K}^*-k^*) - G^*(T^*)\} + \{p(Z)Y^* - c^*(k^*)Y^* - v^*(k^*)\} + (s^*+s_k)k^*, \tag{2}$$

where $Z = X + T^* + Y^*$ and $Z^* = X^* + T + Y$ are total sales (=consumption) in the domestic and foreign countries, respectively. In (1) (and (2)), the first and second terms braced by { } are profits of the domestic (foreign) parent and subsidiary plant, respectively, and the last term is revenue from the governments' FDI subsidies.

Country's welfare

Adopting the same notation and functions as used in the previous subsections, the economic welfare of the domestic and foreign countries, W and W^*, are respectively given by

$$W = \left\{\int_0^Z p(\theta)d\theta - p(Z)Z\right\} + \Pi - sk - s_k k^*, \tag{3}$$

and

$$W^* = \left\{\int_0^{Z^*} p^*(\theta)d\theta - p^*(Z^*)Z^*\right\} + \Pi^* - s^*k^* - s_k^* k, \tag{4}$$

where the first term, $\int_0^Z p(\theta)d\theta - p(Z)Z$ $\left(\int_0^{Z^*} p^*(\theta)d\theta - p^*(Z^*)Z^*\right)$, is the domestic (foreign) consumer's surplus, the second term, Π (Π^*), is the domestic (foreign) firm's profit, the third term, sk (s^*k^*), is the domestic (foreign) subsidy payment for out-flow FDI, and the last term, $s_k k^*$ ($s_k^* k$), is the domestic (foreign) subsidy payment for in-flow FDI. The domestic and foreign governments choose their out-flow and in-flow subsidies so as to maximize their own welfare defined by (3) and (4), respectively. Of course, the negative out-flow (in-flow) FDI subsidy means the out-flow (in-flow) FDI tax.

Though the domestic and foreign governments determine the FDI subsidies in the first stage, and then the domestic and foreign firms decide the FDI sizes in the second stage and output levels in the third stage, this paper will solve these problems from the third stage equilibrium to the first stage equilibrium by backward induction.[7]

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

In the third stage, both the domestic and foreign firms face output-export decisions. The domestic (foreign) firm's control variables are output and export levels, X & T (X^* & T^*), of its parent plant and output level, Y (Y^*), of its subsidiary plant, respectively. Since firms belonging to a Cournot industry act non-

cooperatively, the domestic firm chooses, X, T and Y so as to maximize its profit defined as (1), given the foreign firm's output-export levels and all other exogenous variables in the third stage, and the foreign firm decides, X^*, T^* and Y^* which maximize its profit defined by (2), given the domestic firm's output-export levels and all other exogenous variables in the third stage.

Concentrating on the case of inner solutions since the case of corner solutions is trivial, the first-order conditions for maximizing the domestic and foreign firms' profits defined as (1) and (2) are respectively given by

$$(5)\quad p(Z)+p'(Z)X-C(\bar{K}-k)=0,$$

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

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

and

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

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

$$(10)\quad p(Z)+p'(Z)(T^*+Y^*)-c^*(k^*)=0.$$[8]

Though it is shown that the firms' second-order conditions hold under the demand functions and the cost functions adopted in the previous section, we omit them to save space.[9]

In the first-order conditions, while (5), (9) and (10) are the reaction functions among the domestic parent plant, the foreign parent plant and the foreign subsidiary plant in the domestic market, (6), (7) and (8) are the reaction functions among the domestic parent plant, domestic subsidiary plant and the foreign parent plant in the foreign market. Whether these reaction functions are respectively depicted on a plane as downward- or upward-sloping curves depends on whether the firms' goods are strategically substitutive for, or complementary to, each other. However, it is more reasonable to regard these as being strategically substitutive for each other, since these are homogenous. Then, as is well known, the demand functions satisfy the following conditions, respectively: $p'(Z)+p''(Z)X<0$, $p^{*\prime}(Z^*)+p^{*\prime\prime}(Z^*)(T+Y)<0$, $p^{*\prime}(Z^*)+p^{*\prime\prime}(Z^*)X^*<0$ and $p'(Z)+p''(Z)(T^*+Y^*)<0$, and the reaction curves of the domestic and foreign firms are all downward-sloping.

The Cournot-Nash industry equilibrium in the third stage is given by a vector of (X, T, Y, X^*, T^* and Y^*) that simultaneously satisfies the equation system consisting of (5)-(10). However, it is easily shown that while the equilibrium levels of X, T^* and Y^* are derived by solving (5), (9) and (10), the equilibrium levels of X^*, T and Y are obtained by solving (6), (7) and (8). Then, this separation theorem, the demand functions, and the cost functions mentioned above combine to show that the industry equilibrium in the third stage is locally stable (see the Routh theorem). Therefore, we can present a comparative static analysis at the industry equilibrium of the third stage.

Taking the total differential of (5)-(10) and considering features of the demand functions and the cost functions, one obtains the effects of a change in the firms'

FDI levels, k and k^*, on the industry equilibrium, X, T, Y, X^*, T^* and Y^* (see Appendix 3):

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

Then, these results are summarized as:

Proposition 1: (i) *A rise in the domestic firm's FDI size increases outputs of the domestic and foreign subsidiary plants, but reduces export and output of the domestic parent plant, and vice versa. However, it has no effect on the exports of the foreign parent plant. Similarly,* (*ii*) *an increase in the foreign firm's FDI level raises outputs of the domestic and foreign subsidiary plants, but decreases exports and output of the foreign parent plant, and vice versa. However, it has no effect on the exports of the domestic parent plant.*

Furthermore, from (11) one gets the following relations (see also Appendix 3):

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

While $\frac{\partial Z^*}{\partial k}>0$ and $\frac{\partial Z}{\partial k^*}>0$ entail that a raise in the FDI expands the market size (=consumption) of the host country of its FDI, $\frac{\partial Z}{\partial k}<0$ and $\partial Z\frac{*}{\partial k^*}<0$ demonstrate that an increase in the FDI reduces the market size (=consumption) of the guest country of its FDI. On the other hand, $\frac{\partial Y}{\partial k}+\frac{\partial T^*}{\partial k}+\frac{\partial X^*}{\partial k}>0$ and $\frac{\partial Y^*}{\partial k^*}+\frac{\partial T}{\partial k^*}+\frac{\partial X}{\partial k^*}>0$ mean that a rise in the FDI level increases the output level (=GDP) of the host country of its FDI, but $\frac{\partial Y^*}{\partial k}+\frac{\partial T}{\partial k}+\frac{\partial X}{\partial k}<0$ and $\frac{\partial Y}{\partial k^*}+\frac{\partial T^*}{\partial k^*}+\frac{\partial X^*}{\partial k^*}<0$ indicate that an increase in the FDI results in a reduction of the output level (=GDP) of the guest country of its FDI.

When taken together with Proposition 1, these results show that if the governments can manage the firms' FDI levels by changing the FDI subsidies they can use their FDI subsidies strategically to control firms' market shares and revenues, respectively. Therefore, it is essential for the governments to obtain definite information about the effects of changes in FDI subsidies on the firms' FDI decisions.

4. Firms' Optimal FDI Decisions in the Second Stage

In the second stage, the Cournot domestic and foreign firms non-cooperatively choose their FDI sizes , k and k^*, so as to maximize their own profits, given all of the FDI subsidies, the rival's FDI level, the firms' optimal output-export choices, and

the parameters included in (1) and (2), respectively. Hence, considering that the conditions of (5)–(10) will always hold in the industry equilibrium of the third stage, the first-order conditions for maximizing the domestic and foreign firms' profits in the second stage are respectively given by

$$(13)\quad p'(Z)X\frac{\partial Y^*}{\partial k}+p^{*\prime}(Z^*)\frac{\partial X^*}{\partial k}(T+Y)+C'(\bar{K}-k)(X+T)+V'(\bar{K}-k)-c'(k)Y-v'(k)+(s+s_k^*)=0,$$

and

$$(14)\quad p^{*\prime}(Z^*)X^*\frac{\partial Y}{\partial k^*}+p'(Z)\frac{\partial X}{\partial k^*}(T^*+Y^*)+C^{*\prime}(\bar{K}^*-k^*)(X^*+T^*)+V^{*\prime}(\bar{K}^*-k^*)-c^{*\prime}(k^*)Y^*-v^{*\prime}(k^*)+(s^*+s_k)=0.$$

The second-order conditions of the home and foreign firms, $\prod_{kk}<0$ and $\prod_{k^*k^*}^*<0$, are assumed to be satisfied, for simplification (henceforth, $\prod_{ij}$ and $\prod_{ij}^*$ denote the second-order derivatives of $\prod$ and $\prod^*$ with respect to i and j, $i,j=k,k^*$, respectively).[10]

The equations (13) and (14) are the reaction functions of the domestic and foreign firms, respectively, in firms' FDI decisions. Therefore, the Cournot-Nash industry equilibrium in the second stage is given by k and k^* satisfying (13) and (14) simultaneously. When the firms' FDI are strategically substitutive for (complementary to) each other, the reaction functions in FDI decisions are both depicted as downward- (upward-) sloping curves. Since these two firms engage in FDIs to produce homogenous goods, it is more plausible to assume that the firms' FDIs are strategically substitutive for each other as is similar to their goods. Consequently, $\prod_{kk^*}<0$ and $\prod_{k^*k}^*<0$ hold.

Furthermore, the firm's marginal profit, $\prod_k(\prod_{k^*}^*)$, with respect to its own FDI size, $k(k^*)$ is generally regarded as being more sensitive to a change in its own FDI size, $k(k^*)$, than to a change in its rival's FDI size, $k^*(k)$, respectively. Therefore, $|\prod_{kk}|>|\prod_{kk^*}|$ and $|\prod_{k^*k^*}^*|>|\prod_{k^*k}^*|$ hold. Then, these conditions and the second-order conditions combine to ensure that the industry equilibrium in the second stage is locally stable since $\prod_{kk}<0$, $\prod_{k^*k^*}^*<0$ and $0<\prod_{kk}\prod_{k^*k^*}^*-\prod_{kk^*}\prod_{k^*k}^*$ hold (see the Routh theorem).

As is obvious from (13) and (14), both the industry equilibrium FDI levels, k and k^*, depend on out-flow and in-flow FDI subsidies, s, s^*, s_k and s_k^*, which are determined by the domestic and foreign governments in the first stage. However, (13) and (14) demonstrate that s and s_k^* (s^* and s_k) have the same effects on the industry equilibrium. Then, it is impossible to discern the effects of changes in s and s_k^*, and of changes in s^* and s_k, on the equilibrium. Therefore, let us now examine these effects more carefully.

Taking the total differential of (13) and (14), and considering the second-order conditions, the negative slope conditions of firms' FDI reaction curves and the stability conditions of the industry equilibrium, one can obtain the effects of changes in s, s_k^*, s^* and s_k on the industry equilibrium:

$$(15)\quad \frac{\partial k^*}{\partial s}=\frac{\partial k^*}{\partial s_k^*}=-\frac{\prod_{k^*k}^*}{\Omega}>0,$$

$$\frac{\partial k}{\partial s}=\frac{\partial k}{\partial s_k^*}=-\frac{\prod_{k^*k^*}^*}{\Omega}>0,$$

$$\frac{\partial k}{\partial s^*}=\frac{\partial k}{\partial s_k}=-\frac{\prod_{kk^*}}{\Omega}>0, \tag{16}$$

$$\frac{\partial k^*}{\partial s^*}=\frac{\partial k^*}{\partial s_k}=-\frac{\prod_{kk}}{\Omega}>0,$$

where $\Omega=\prod_{kk}\prod_{k^*k^*}^*-\prod_{kk^*}\prod_{k^*k}^*>0$. Therefore, considering $|\prod_{kk}|>|\prod_{kk^*}|$ and $|\prod_{k^*k^*}^*|>|\prod_{k^*k}^*|$, (15) and (16) combine to present the next proposition:

Proposition 2: *A rise in domestic or foreign FDI subsidy increases both domestic and foreign FDI sizes, and vice versa. However, the effect of a change in out-flow (in-flow) FDI subsidy on the size of an out-flow (in-flow) FDI is larger than that on an in-flow (out-flow) FDI level, in terms of the absolute value.*

It is quite natural that when the domestic (foreign) government increases its out-flow (in-flow) FDI subsidy the domestic (foreign) firm increases its FDI level, and thus the foreign (domestic) firm also raises its FDI level. Under the capital constraint, since a rise in the domestic FDI size implies an equivalent reduction of the domestic ADI level, it induces an increase in the foreign FDI size and a reduction in the foreign ADI size. Therefore, Proposition 2 also coincides with our intuitive conjecture.

It is demonstrated from this proposition that both the domestic and foreign firms adjust their FDI levels smoothly when the governments change the FDI subsidies marginally. Therefore, a small change in the FDI subsidy does not cause drastic changes in firms' plant locations as is indicated by Markusen *et al*. (1993 and 1995) when firms' plant sizes, as well as plant locations, are determined endogenously. On the contrary, there exists a possibility that such drastic changes in plant locations are not induced by small changes in the FDI subsidies, even if the firms have fixed costs.

Furthermore, this proposition entails that both the domestic and foreign governments can control the rival firm's FDI (ADI) size by changing appropriately one or both of their out-flow and in-flow FDI subsidies. Therefore, the governments can use the FDI subsidies as strategic FDI policies that manage the economic welfare in the rivals' countries.

5. Optimal FDI Subsidies in the First Stage

In the first stage, the domestic and foreign governments non-cooperatively set the FDI subsidies, (s, s_k) and (s^*, s_k^*), that maximize their own economic welfare, which are defined respectively as (3) and (4). Thus, taking into consideration that (5)–(12) hold at the equilibrium in the third stage and that (13)–(16) hold at the equilibrium in the second stage, the first-order conditions for the domestic welfare maximization are given by

$$-\frac{\partial k}{\partial s}s-\frac{\partial k^*}{\partial s}s_k-\frac{\partial k}{\partial s}A+\frac{\partial k^*}{\partial s}(B+H)=0, \tag{17}$$

$$-\frac{\partial k}{\partial s_k}s-s_k\frac{\partial k^*}{\partial s_k}-k^*-\frac{\partial k}{\partial s_k}A+\frac{\partial k^*}{\partial s_k}(B+H)=0, \tag{18}$$

where $A=p'(Z)Z\frac{\partial Z}{\partial k}>0$, $B=$

$\left\{p^{*\prime}(Z^*)(T+Y)\frac{\partial X^*}{\partial k^*}-p'(Z)Z\frac{\partial Z}{\partial k^*}\right\}>0$ and $H=p'(Z)X\left(\frac{\partial T^*}{\partial k^*}+\frac{\partial Y^*}{\partial k^*}\right)<0$. Similarly, the first-order conditions of the foreign government are

$$(19)\qquad -\frac{\partial k^*}{\partial s^*}s^*-\frac{\partial k}{\partial s^*}s_k^*-\frac{\partial k^*}{\partial s^*}A^*+\frac{\partial k}{\partial s^*}(B^*+H^*)=0,$$

$$(20)\qquad -\frac{\partial k^*}{\partial s_k{}^*}s^*-s_k^*\frac{\partial k}{\partial s_k^*}-k-\frac{\partial k^*}{\partial s_k^*}(B^*+H^*)=0,$$

where $A^*=p^{*\prime}(Z^*)Z^*\frac{\partial Z^*}{\partial k^*}>0$, $B=\left\{p'(Z)(T^*+Y^*)\frac{\partial X}{\partial k}-p^{*\prime}(Z^*)Z^*\frac{\partial Z^*}{\partial k}\right\}>0$ and $H^*=p^{*\prime}(Z^*)X^*\left(\frac{\partial T}{\partial k}+\frac{\partial Y}{\partial k}\right)<0$. To avoid tedious and inessential arguments, it is also assumed here that the second-order conditions for maximizing the domestic and foreign welfare are all satisfied in the neighborhood of the equilibrium. Since the equilibrium in the first stage is expressed by (17)-(20), the optimal domestic FDI subsidies are symmetric with the optimal foreign FDI subsidies. Thus, what we can say about the former policies is also true with respect to the latter policies. Therefore, we concentrate our attention on the domestic subsidies.

Considering (11) and (12), we obtain the optimal domestic out-flow and in-flow subsidies, s^e and s_k^e, from (17) and (18), respectively:

$$(21)\qquad s^e=k^*\frac{\partial k^*}{\partial s}\Omega-A,$$

and

$$(22)\qquad s_k^e=\left(B+H-k^*\frac{\partial k}{\partial s}\Omega\right).$$

In (21) and (22), since signs of $k^*\frac{\partial k^*}{\partial s}\Omega$ and $-A$ (B and $H-k^*\frac{\partial k}{\partial s}\Omega$) are different from each other and depend on slopes of the FDI reaction curves in the second stage, it is impossible to judge the signs of the optimal domestic FDI subsidies, s^e and s_k^e. Therefore, in this section, we examine the four typical cases that depend on the slopes of the FDI reaction curves in the second stage: Case 1: $\frac{\partial k}{\partial s}$ and $\frac{\partial k^*}{\partial s}$ are both large, Case 2: $\frac{\partial k}{\partial s}$ and $\frac{\partial k^*}{\partial s}$ are both small, Case 3: $\frac{\partial k}{\partial s}$ is small and $\frac{\partial k^*}{\partial s}$ is large, and Case 4: $\frac{\partial k}{\partial s}$ is large and $\frac{\partial k^*}{\partial s}$ is small.

Case 1 corresponds to the case in which the marginal profit of the foreign firm with respect to the foreign FDI is very sensitive to both the domestic and foreign FDI sizes: that is, $|\prod_{kk^*}^*|\fallingdotseq\infty$ and $|\prod_{k^*k^*}^*|\fallingdotseq\infty$. Hence, considering (15), the effects of a change in the domestic out-flow subsidy, s, on the domestic and foreign FDI levels, k and k^*, are both large enough to give $k^*\frac{\partial k}{\partial s}>(B+H)\Omega$ and $k^*\frac{\partial k^*}{\partial s}>A\Omega$, which in turn implies $s^e>0$ and $s_k^e<0$. Case 2 is the opposite of Case 1, and $\frac{\partial k}{\partial s}\fallingdotseq 0$ and $\frac{\partial k^*}{\partial s}\fallingdotseq 0$ hold. Then, substituting these results into (21) and (22), we obtain $s^e<0$ but the sign of s_k^e is still ambiguous. In case 3, while the marginal profit of the foreign firm with respect to the foreign FDI is very sensitive to the domestic FDI, it is not

sensitive to the foreign FDI: that is, $|\prod^*_{kk^*}| \fallingdotseq \infty$ and $|\prod^*_{k^*k^*}| \fallingdotseq 0$, which entails $\frac{\partial k}{\partial s} \fallingdotseq \infty$ and $\frac{\partial k^*}{\partial s} \fallingdotseq 0$. Therefore, considering this result, we get $s^e > 0$ but the sign of s^e_k is still ambiguous. Finally, Case 4 is the opposite of Case 3. Then, $\frac{\partial k}{\partial s} \fallingdotseq 0$ and $\frac{\partial k^*}{\partial s} \fallingdotseq \infty$ hold. Therefore, taking into consideration these results, one gets definitely $s^e < 0$ and $0 < s^e_k$. Furthermore, considering that the same reasoning is applied to the optimal foreign FDI subsidies, the above arguments yield the next proposition:

Proposition 3: (i) *The optimal domestic (foreign) out-flow FDI subsidy is always positive in the case in which a marginal profit of the foreign (domestic) firm with respect to the foreign (domestic) FDI level is very sensitive to the domestic (foreign) FDI level, and vice versa, while* (ii) *the optimal domestic (foreign) in-flow FDI subsidy is negative in the case where a marginal profit of the foreign (domestic) firm with respect to the foreign (domestic) FDI level is very sensitive to both domestic and foreign FDI levels, and is positive in the case where a marginal profit of the foreign (domestic) firm with respect to the foreign (domestic) FDI is very sensitive to the foreign (domestic) FDI level but unresponsive to domestic (foreign) FDI. However,* (iii) *the sign of optimal domestic (foreign) in-flow FDI subsidy is ambiguous in the case where a marginal profit of the foreign (domestic) firm with respect to the foreign (domestic) FDI level is not sensitive to foreign (domestic) FDI level.*

It has long been believed that while the optimal out-flow FDI subsidy is negative, the optimal in-flow FDI subsidy is positive, since a negative out-flow FDI subsidy prevents the out-flow FDI while a positive in-flow FDI subsidy promotes the in-flow FDI (see Proposition 2). However, Proposition 3 entails that such a belief is not always true. In the actual world, some countries that are unable to pay a FDI subsidy by cash offer other avenues for the in-flow FDI such as zero-profit taxes and/or zero-rent lands, but such preferential political instruments would not be appropriate in some cases. Governments must pay careful attention to the circumstances they face when determining the FDI subsidies.

It is also shown, from Proposition 3 when taken together with Propositions 1 and 2, that the FDI subsidies may be used as strategic policies if they are used appropriately. Propositions 1 and 2 combine to demonstrate that the effects of changes in the FDI sizes on firms' output-exports and the effects of changes in the FDI subsidies on firms' FDI levels are all definitely determined, though Proposition 3 states that the signs of the optimal FDI subsidies are not judged definitely. Consequently, the governments can use FDI subsidies as a means to implement strategic policies, provided that they use them appropriately.

Moreover, proposition 3 raises a significant issue. Apparently, some results in this proposition are contrary to those of some other papers. For example, Ishii (2006) finds that the optimal domestic and foreign out-flow FDI subsidies are always negative. However, such differences stem from differences in the models used. While the present paper introduces a capital constraint, endogenous and continuous ADI and FDI adjustment but excludes a labor

assessment, Ishii (2006) adopts a labor assessment, but assumes no capital constraint, constant size of parent plant. Clearly, these arguments indicate that there is no general theory about the optimal FDI subsidies. Therefore, it would be necessary and useful to establish several models that are regarded as plausible from standpoints of the present world and to analyze optimal FDI subsidies by using such models, in order to apply suitable subsidy policies to different situations.

6. Concluding Remarks

Establishing a generalized model of an international Cournot industry where the domestic and foreign firms choose endogenously both locations and sizes of their FDI and ADI under capital constraints, we first investigated the effects of FDI subsidies on firms' output, export and FDI choices and then discussed the optimal FDI subsidies chosen by the domestic and foreign governments. We thereby obtained some interesting and useful results, which are summarized as the three propositions in the previous sections. Hence, we do not repeat them in this section, but refer only to some other of general characteristic features.

It was found that the governments can use FDI subsidies to implement strategic policies, provided that careful attention is paid to prevailing real-world conditions. Even if the governments cannot guess the optimal levels of FDI subsidies from a theoretical point of view (Proposition 3), they might gather all information necessary for determining the optimal FDI subsidies in the real world, according to the theoretical suggestions presented in this paper. Since it is certain what will be the effects of changes in the FDI sizes on firms' output-export choices and the effects of changes in the FDI subsidies on firms' FDI decisions (Proposition 2), the governments can effectively manage the in-flow and out-flow FDI levels by combining the in-flow and out-flow FDI subsidies.

Furthermore, it could be shown, though it is not discussed explicitly in the present paper, that the FDI subsidies do not have such drastic effects on the firms' plant choices as are indicated by Markusen, *et al*. (1993 and 1995). In this paper, since the firms can endogenously determine the plant sizes in the second stage, the costs for constructing their plants are also control variables even though these are fixed when the firms decide their output-export levels in the third stage. Therefore, the firms can vary a certain fraction of their plant construction costs by changing their plant sizes when the governments change their FDI subsidies. In such a case, the firms would adjust their plant sizes smoothly before they drastically open or close the plants of constant sizes.

Finally, the following point from Proposition 3 should be emphasized. It seems quite natural that the governments should be responsible for controlling FDI flows in order to improve their own economic welfare. Then, the governments must intervene in all the firms' FDI choices from the standpoint of efficient resource allocation, and thus the out-flow FDI tax and the in-flow FDI subsidy are regarded as inevitable policies. As a result, there is a possibility that the international economy

would drift away from a free trade and/or FDI economy, contrary to the findings of Janeba (1998) and Ishii (2001) that the world economy approaches to a free trade economy as firms have their subsidiary plants in their rivals' country.

Of course, the present model cannot explain all aspects of the multinational firms' FDI-output-trade decisions and the governments' FDI subsidy determinations, and thus it is clearly irrelevant to some industries and policies. In order to investigate other aspects appropriately, it is necessary to extend the model so as to include such aspects correctly. The present model assumes a homogenous good, two countries, and a three-stage game of a Cournot duopoly. However, for some industries the assumptions of heterogeneous goods, a Bertrand duopoly and more than three countries might be plausible. Moreover, though this paper excludes other types of political instrument that may have some effects on firms' FDI decisions, it would be interesting and useful to compare the FDI subsidies with some other policies.

Appendices

Appendix 1.

Here we examine the theoretical plausibility of the assumption that in a homogenous good model the subsidiaries supply their products only to the countries where they are located.

Suppose that the domestic subsidiary also supplies its products to the foreign and domestic countries. Then the profit of the domestic multinational firm defined by (1) is replaced by

$$(1)' \qquad \Pi = p(X+T^*+Y^*+y)(X+y) + p^*(X^*+T+Y+y^*)(T+Y) - C(X+T) - G(T) - c(k)(Y+y) - v(k) - h(y) + (s+s_k^*)k,$$

where y is the domestic subsidiary's exports, $h(y)$ is its export cost function with $h'(y) > 0$, and other notations and functions are all the same as in Section 2. In this case the control variables of the domestic multinational firm are X, T, Y and y in (1)′. Thus, assuming an inner equilibrium, the first-order condition of the domestic multinational firm is given by

$$\begin{aligned}
&\text{(i)} && p'(Z)(X+y) + p(Z) - C = 0,\\
&\text{(ii)} && p^{*\prime}(Z^*)(T+Y) + p^*(Z^*) - G'(T) - C = 0,\\
&\text{(iii)} && p^{*\prime}(Z^*)(T+Y) + p^*(Z^*) - c(k) = 0,\\
&\text{(iv)} && p'(Z)(X+y) + p(Z) - h'(y) - c(k) = 0,
\end{aligned}$$

where the second-order condition is assumed to be satisfied, for simplification. Thus, the first-order condition given by (i)–(iv) presents

$$\text{(A.1)} \qquad g'(T) + h'(y) = 0.$$

However, this is inconsistent with the positive marginal export costs. This implies, from a theoretical point of view, that there is no possibility that the domestic subsidiary supplies its products to both of the foreign and domestic countries in a homogeneous good model. Therefore, considering the theoretical reasoning from (A.1) and the empirical observations of some multinational firms in the real world, it is reasonable to assume, for present purposes, that the domestic subsidiary sells its products only in the foreign country but does not export back them to the domestic country. The same reasoning applies to the foreign multinational firm.

Appendix 2.

From (6) and (7), one gets, as a condition under which exports of the domestic multinational firm is positive,

$$G'(T)+C(\bar{K}-k)=c(k). \qquad \text{(A.2)}$$

This shows that the domestic multinational firm chooses its exports T so as to equate the (effective) unit export cost, $G'(T)+C(\bar{K}-k)$, to the unit production cost of its subsidiary, $c(k)$. One might suppose that since $C(\bar{K}-k)$ and $c(k)$ are both given to the domestic multinational firm in the third stage, T is zero (a corner solution) when $C(\bar{K}-k)$ is larger than $c(k)$ is. However, while $C(\bar{K}-k)$ and $c(k)$ are parameters in the third stage, they are control variables, not parameters, in the second stage. Therefore, the domestic multinational firm that intends to supply its products to the foreign country via the two routes of exporting and overseas production decides $C(\bar{K}-k)$ and $c(k)$ in the second stage so that its exports in the third stage can be positive. The same reasoning applies to the foreign multinational firm.

Appendix 3.

Here, we will show only the derivation of (12), since that of (11) is obtained by exchanging variables with asterisks with those without asterisks and variables without asterisks with those with asterisks. The effects of changes in k and k^* on X, T^* and Y^* are respectively obtained by taking the total differential of (9), (10) and (5):

$$\text{(A.3)}\quad \begin{pmatrix}\Delta_{11} & \Delta_{12} & \Delta_{13}\\ \Delta_{21} & \Delta_{22} & \Delta_{23}\\ \Delta_{31} & \Delta_{32} & \Delta_{33}\end{pmatrix}\begin{pmatrix}\frac{\partial T^*}{\partial k}\\ \frac{\partial Y^*}{\partial k}\\ \frac{\partial X}{\partial k}\end{pmatrix}=\begin{pmatrix}0\\ 0\\ -C'(\bar{K}-k)\end{pmatrix},$$

and

$$\text{(A.4)}\quad \begin{pmatrix}\Delta_{11} & \Delta_{12} & \Delta_{13}\\ \Delta_{21} & \Delta_{22} & \Delta_{23}\\ \Delta_{31} & \Delta_{32} & \Delta_{33}\end{pmatrix}\begin{pmatrix}\frac{\partial T^*}{\partial k^*}\\ \frac{\partial Y^*}{\partial k^*}\\ \frac{\partial X}{\partial k^*}\end{pmatrix}=\begin{pmatrix}-C^{*\prime}(\bar{K}^*-k^*)\\ c^{*\prime}(k^*)\\ 0\end{pmatrix},$$

where $\Delta_{11}=p''(Z)(T^*+Y^*)+2p'(Z)-G^{*\prime\prime}(T^*)$, $\Delta_{12}=\Delta_{21}=\Delta_{22}=p''(Z)(T^*+Y^*)+2p'(Z)$, $\Delta_{13}=\Delta_{23}=p''(Z)(T^*+Y^*)+p'(Z)$, $\Delta_{31}=\Delta_{32}=p''(Z)X+p'(Z)$, $\Delta_{33}=p''(Z)X+2p'(Z)$ and $\Delta=G''(T^*)p'(Z)\{p''(Z)+3p'(Z)\}<0$. Thus, while we can obtain $\frac{\partial T^*}{\partial k}$, $\frac{\partial Y^*}{\partial k}$, and $\frac{\partial X}{\partial k}$ from (A.3), we can get $\frac{\partial T^*}{\partial k^*}$, $\frac{\partial Y^*}{\partial k^*}$ and $\frac{\partial X}{\partial k^*}$ from (A.4). Similarly, we can derive $\frac{\partial T}{\partial k}$, $\frac{\partial Y^*}{\partial k}$, $\frac{\partial X^*}{\partial k}$, $\frac{\partial T}{\partial k^*}$, $\frac{\partial Y}{\partial k^*}$ and $\frac{\partial X^*}{\partial k^*}$ from (8), (9) and (13).

FootNotes

1 As is well known, not only FDI subsidies, but also trade policies such as tariffs, export subsidies and voluntary export restraints, and even corporate taxes and consumption taxes, affect the firms' optimal FDI levels. However, since such political instruments, apart from the FDI subsidies, have their own purposes, it is rare that they are used to control the FDI sizes directly. Furthermore, the effects of these other policies on the FDI decisions have already been analyzed in many papers including Brander and Spencer (1987), Flamm and Reiss (1993), Hillman and Ursprung (1993), Konishi, Saggi and Weber (1999) and Williamson (1986). Therefore, this paper concentrates on the effects of FDI subsidies on the firms' optimal FDI choices.

2 Markusen, Edward and Olewiler (1993)

have established a model that considers the firms' endogenous plant locations when analyzing the optimal environmental pollution policies. However, they implicitly assumed that firms are 'footloose', as indicated by Motta and Thisse (1994), and that firms' plant sizes are exogenously given. However, in analyzing the multinationals that already have their parent plants in their own countries and intend to construct subsidiary plants in other countries, the above assumptions are rather strange.

3 The present model also depends on Motta and Thisse (1994), Brander and Spencer (1987) and Hoel (1997). This paper assumes, following Motta and Thisse, that both of the domestic and foreign firms already have parent plants in their own countries when the game begins.

4 For example, while the Toyota automobile company in Japan supplies its products to Japan and the U.S.A., U.S.A. Toyota sells almost of all its products in the U.S.A. Further, some research has found that many subsidiaries do not export their products to the parent countries in which their parent firms produce homogenous goods (see, for example, Belderbos and Sleuwaegen (1996), Blonigen (2001) and Baldwin and Ottaviano (2001)). With respect to the theoretical explanation, see Appendix 1.

5 The strictly increasing and convex plant construction cost functions and the constant unit production costs both hold when the production functions of production facilities are strictly increasing and concave with respect to capital stocks (= plant scales) and homogenous to degree one with respect to the other factors except for capital stocks, respectively.

6 Though detailed discussion is here omitted, it is easily shown that the increasing marginal export costs, $G''(T) > 0$ and $G^{*\prime\prime}(T^*) > 0$, are necessary in the neighborhood of the equilibrium in order to ensure both the second-order conditions for profit maximization of the domestic and foreign firms and the stability conditions of the industry equilibrium in the second stage (see the Routh theorem).

7 The present model reduces to that of Ishii (2001) when the parent and subsidiary plant sizes are both exogenous, and to that of Ishii (2006) when the parent plant size is exogenous but the subsidiary plant size is endogenous.

8 With respect to the inner solution, see Appendix 2.

9 The second-order condition for profit maximization of the domestic (foreign) multinational firm is the Hessian H (H*) is negative definite in the neighborhood of the equilibrium, where, adopting notations of $D_{11} = p''(Z)X + 2p'(Z)$, $D_{22} = p^{*\prime\prime}(Z^*)(T+Y) + 2p^{*\prime}(Z^*) - G'(T)$, and $D_{23} = D_{32} = D_{33} = p^{*\prime\prime}(Z^*)(T+Y) + 2p^{*\prime}(Z^*)$, H is defined as:

$$\mathrm{H} = \begin{pmatrix} D_{11} & 0 & 0 \\ 0 & D_{22} & D_{23} \\ 0 & D_{32} & D_{33} \end{pmatrix}.$$

10 In (13), if the reasonable assumptions of $\lim_{k=0} v'(k) = 0$ and $\lim_{K=0} V'(K) = 0$ are adopted additionally, then a corner solution of $k = 0$ or $K = 0$ is excluded. Similar reasoning applies to (14). Therefore, in this paper we analyze the inner solution case because the corner solution case is trivial.

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