I. Introduction

Ever since 1980's, there have been serious challenges on traditional Hescher-Ohlin trade theory which is based on the assumption of perfect competition. Recognizing that international competition among firms in many industries is imperfectly competitive, the study of trade theory and policy under imperfect competition becomes a new subject. Among other things, Brander (1981) claimed firstly that when international markets are characterized by oligopolistic competition, the pattern of trade is indeed intra-industry trade rather than inter-industry trade. Later on , trade theorists began to focus on the profit-shifting motive for trade policy under oligopoly, notably including Brander and Spencer (1984, 1985), Spencer and Brander (1983), Venables (1985), Harris (1985), Eaton and Grossman (1986), Hwang and Mai (1991), Mai and Hwang (1987) and others. In particular, Brander and Spencer (1985) argued that if the domestic government can credibly pre-commit itself to pursue a particular trade policy before firms make output decisions, then an export subsidy in a Cournot-Nash equilibrium is optimal and such an export subsidy can actually move the domestic firm to what would be, in the absence of a subsidy, the Stackelberg leader position. However, this result can also be achieved by other means. For example, Spencer and Brander (1983) showed that a government can credibly commit itself to R&D subsidies before the R&D decisions are made by private firms.

In fact, the type of optimal strategic export policy is sensitive to many industry-specific factors such as the cost structures (or technologies) of producers. It then becomes clear that if policy makers do not have relevant information about the firm's technology costs, the government could very likely adopt the wrong type of policy.

Rather than taking the technology as given, we endogenize the cost level by assuming that it is a result of costly investment, like R&D, by forward-looking and optimizing agents. More specifically, the present paper intends to explore the long-run consequences of active trade policies, namely how the pursuit of profit-shifting technology and/or export policies can affect the long-run choice of technology by producers.[1] To this end, we wish to pursue the following issues:

(i) We will examine the effects of technology and export subsidies on the technology choice and compare the superiority of both policies.

(ii) If both policies can be adopted and implemented simultaneously or sequentially, what is the welfare effect of simultaneous policy implementation on the technology choice compared with that of sequential policy implementation?

(iii) Which policy implementation requires a higher government subsidy expenditure?

The structure of the paper is as follows. Section II points out technology distortion under free-trade equilibrium. Section III considers optimal technology subsidy only. In Section IV, optimal export subsidy is examined. Section V assumes that the domestic government can adopt technology and export subsidies simultaneously and then investigate their welfare implications. Section VI considers instead that technology and export subsidies are implemented sequentially. In Section VII, the ranking of the two policy combination is made. Concluding remarks are provided in the final section.

II. Technology Distortion under Free-trade Equilibrium

We use the simplest possible structure capable of bringing out the main points. There are two competing firms : one domestic firm and one foreign firm. We assume that both firms produce only for a third market and there is no consumption in the producing countries. Assume further that the foreign firm is well-established and its technology level is predetermined at $\bar{c}^*$. The free-trade equilibrium is characterized by two stages. In the first stage, the domestic firm chooses its best technology level by selecting a level of marginal cost c at the fixed cost F. In general, levels of technology may be characterized as "backward" (a high marginal cost and a low fixed cost technology) and "advanced" (a low marginal cost and a high fixed cost technology). In the second stage, the domestic firm competes with the foreign firm in a third country output market in the second stage. Within this framework, we obtain a sub-game perfect equilibrium as our solution. Under this setting, the profit functions of the two firms are specified as follow:

(1) $\pi(q, q^*) = R(q, q^*) - cq - F(c)$

(2) $\pi^*(q, q^*) = R^*(q, q^*) - c^* q^* - F^*(c^*)$

where R is total revenue; q is the output of the domestic firm; c is its marginal cost which is assumed to be constant in the second stage; F is (i.e., capital cost) fixed cost ; and variables with asterisks denote that they are associated with the foreign firm. Note that there is a trade-off between the marginal cost and the fixed cost. We assume that F(c) is twice continuously differentiable with $F'(c) < 0$ and $F''(c) > 0$. That is, a lower marginal cost is achieved at the expense of a higher fixed cost. In fact, we can think of F as an irreversible investment in cost-reducing R&D.

We solve for the equilibrium in the standard backward fashion. In stage two, each firm maximizes its profit with respect to its own output. The Cournot-Nash equilibrium is characterized by the following first-order conditions:

(3) $\pi_q = R_q - c = 0$

(4) $\pi^*{}_{q*} = R^*{}_{q*} - c^* = 0$

We also use the following second-order and stability conditions
:

(5) $\pi_{qq*} = p''q + p' < 0 \quad ; \quad \pi_{q*q} = p''q^* + p' < 0$

(6) $\pi_{qq} \equiv p''q + 2p' < \pi_{qq*} \quad ; \quad \pi^*{}_{q*q*} \equiv p''q^* + 2p' < \pi^*{}_{q*q*}$

where "prime" denotes derivatives

Equation (5) means that the marginal revenue declines with an increase in the output of the other firm. This is equivalent, given the satisfaction of the second-order conditions, to reaction functions being downward sloping. Equation (6) means that the own effects of output on marginal profit dominate the cross effects.

Conditions (5) and (6) imply:

(7) $D \equiv \pi_{qq}\pi^*{}_{q*q*} - \pi_{qq*}\pi^*{}_{q*q*} > 0$

Given the outcome in stage two, the domestic firm chooses c in stage one ,for a given foreign marginal cost c*, so as to maximize its profits:

(8) π(c,c*)=R(q(c,c*),q*(c,c*))-cq(c,c*)-F(c)

The technology equilibrium of the domestic firm requires:

(9) $\frac{\partial\pi}{\partial c} = \frac{\partial\pi}{\partial q}q_c + \frac{\partial\pi}{\partial q^*}q_c{}^* + \frac{\partial\pi}{\partial c} = 0$

$R_{q*}q_c^* = q + F_c < 0$

where $\frac{\partial\pi}{\partial q} = 0$ from (3) $\quad R_{q*} = p'q < 0$ and $q_c^* \equiv \frac{dq^*}{dc} = \frac{-\pi^*_{q*q}}{D} > 0$.

Before interpreting (9), let us discu $\bar{c}$ e prop $\frac{\partial TC}{\partial C}$ he domestic firm's total cost function which is defined as TC = $\bar{c}$ F(c). We normally expect that the total cost function is convex with respect to technology, i.e., $\frac{\partial^2 TC}{\partial c^2} > 0$ as depicted in Figure 1. Note that the right-hand side of (9) is equivalent to $\frac{\partial TC}{\partial c} = q + F_c$. As shown in Figure 1, the total cost is minimized at $\bar{c}$ when $\frac{\partial TC}{\partial c}$ =q+F_c = 0. With this in mind, it follows from (9) that (q + F_c) < 0 implies that the optimal $\bar{c}$ is at the left-hand side of the cost-minimizing $\bar{c}$, say c_1 as depicted in Figure 1. Therefore, anticipating the output rivalry in the last-stage game, the domestic firm chooses a technology level which is more advanced (i.e., a lower c) than the cost-minimizing technology level. In other words, the duopolistic interaction between firms causes the domestic firm to twist its technology choice away from the regular cost-minimization in order to enjoy more profits in the output game. If there were no foreign firm, the domestic firm would have chosen the technology minimizing the total cost, given any output level. In the presence of foreign firm, the domestic firm's profit is maximized if the marginal gain from a more advanced technology (i.e., $R_{q*}q^*_c$) is equal to its marginal cost (i.e., q + F_c). However, as the domestic firm is not minimizing its technology cost, there is a technology distortion from the domestic social welfare point of view. Moreover, the domestic firm is not acting as a Stackelberg leader in output competition, there is a room for the domestic government to intervene so as to raise its national welfare.

To remove this distortion, the government can use either technology and/or export subsidy to encourage its firm to compete with the foreign firm in the third market. In each case, we examine the subgame perfect equilibrium in which the government understands the structure of the industry and is able to get a credible subsidy in advance of the output and technology decisions by firms. Under this situation, the profit functions of the two firms are specified as follows:

$$(10)\pi(q,q^*) = R(q,q^*) - cq - F(c) + sq + zF(c)$$

$$(11)\pi^*(q,q^*) = R^*(q,q^*) - c^*q^* - F^*(c^*)$$

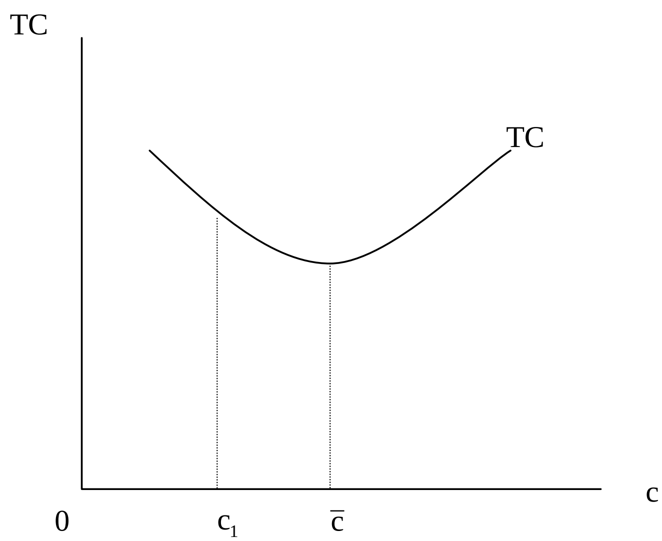

Figure 1. The Total Cost Function

where s and z denote the export and technology subsidies, respectively.

The first-order conditions for profit maximization in this (third) stage are:

$$(12) \pi_q = R_q - c + s = 0$$
$$(13) \pi^*_{q^*} = R^*_{q^*} - c^* = 0$$

Assume that the second-order and stability conditions are met, the comparative static effects of s, z and c on q and q^* are derivable as follows:

$$(14-1) q_c \equiv \frac{dq}{dc} = \frac{\pi^*_{q^*q^*}}{D} < 0$$
$$(14-2) q^*_c \equiv \frac{dq^*}{dc} = \frac{-\pi^*_{q^*q^*}}{D} > 0$$
$$(14-3) q_s \equiv \frac{dq}{ds} = \frac{-\pi^*_{q^*q^*}}{D} > 0$$
$$(14-4) q^*_s \equiv \frac{dq^*}{dc} = \frac{\pi^*_{q^*q^*}}{D} < 0$$
$$(14-5) q_z \equiv \frac{dq}{dz} = 0$$
$$(14-6) q^*_z \equiv \frac{dq^*}{dz} = 0$$

which implies that q = q(s, c) and q* = q* (s,c)

This completes the third-stage analysis. Now, let us examine the second stage problem. In the second stage, the domestic firm chooses c so as to maximize its profits as specified in (10) which yields the following first-order condition:

$$(15) \frac{\partial \pi}{\partial c} = \frac{\partial \pi}{\partial q} q_c + \frac{\partial \pi}{\partial q^*} q^*_c + \frac{\partial \pi}{\partial c} = 0 \quad or$$
$$R_{q^*} q^*_c + zF_c = q + F_c$$
$$where \quad \frac{\partial \pi}{\partial q} = 0 \quad from\ (12).$$

Note that the domestic firm's technology cost is minimized when q + F_c = 0 for any given q. A positive technology subsidy would deviate the domestic firm's technology equilibrium farther away from the cost-minimizing level.

Assuming the second-order condition to be satisfied, the effects of z and s on c is derivable by totally differentiating (15) with respect to c, s and z:

$$(16-1) c_z \equiv \frac{dc}{dz} = -\frac{\pi_{cz}}{\pi_{cc}}$$

$$(16-2) c_s \equiv \frac{dc}{ds} = -\frac{\pi_{cz}}{\pi_{cc}}$$

where

$$\pi_{cz} = F_c < 0$$

$$\pi_{cs} = (R_{q^*q} q_s + R_{q^*q^*} q_s^*) q_c^* + R_{q^*} q_{cs}^* - q_s$$

In general, the sign of π_{cs} is ambiguous as it depends on the sign of p'''. Under the linear demand assumption, it l $\pi_{cs} = -q_s < 0$[2] which together with π_{cs}<0 implies that c=c(z,c) with c_z<0 and c_s<0.

we are now in a position to investigate the optimal domestic technology and /or export subsidies.

III. Optimal Technology subsidy

Assume first that the government imposes only the technology subsidy. The optimal technology subsidy is found by maximizing the domestic welfare W, which is the profit of the domestic firm less the cost of the subsidy.

(17)W(z)= π -zF(c)

From (17), the first-order condition for the welfare maximizing technology subsidy is given by :

$$(18)\,\frac{dW}{dz} = \frac{\partial \pi}{\partial c} c_z + \frac{\partial \pi}{\partial z} - F - zF_c c_z = 0$$

$$\text{Since } \frac{\partial \pi}{\partial c} = 0 \quad \text{from(15) and } \frac{\partial \pi}{\partial z} = F, \text{ (18) reduces to :}$$

$$(19) - zF_c C_z = 0 \text{ or } z = 0$$

The optimal technology subsidy is nil. This is because the domestic firm has already taken into account the rivalry effect in the export market in determining its optimal technology. There is no room for the government to intervene. Therefore, we have:

Proposition 1. *The optimal technology policy is laissez-faire. The technology subsidy can not remove or reduce the technology distortion.*

IV. Optimal Export Subsidy

Alternatively, assume that the government imposes only the export subsidy and announces it prior to the domestic firm's technology choice. In this case, the domestic welfare is defined as:

$$(20)\,W(s) = \pi - sq$$

The first-order condition for welfare-maximizing export subsidy is derivable as:

$$(21)\,\frac{dw}{ds} = \frac{\partial \pi}{\partial c}\frac{\partial c}{\partial s} + \frac{\partial \pi}{\partial s} + \frac{\partial \pi}{\partial q}\frac{\partial q}{\partial s} + \frac{\partial \pi}{\partial q^*}\frac{\partial q^*}{\partial s} - q - s\frac{dq}{ds} = 0 \quad \text{or}$$

$$s = \frac{p' q q_s^*}{q_c c_s q_s} > 0 \text{ if the reaction function of the foreign firm is negatively sloped.}$$

$$\text{where } \frac{\partial \pi}{\partial c} = 0 \text{ from } (15) \text{ and } \frac{\partial \pi}{\partial q} = 0 \text{ from } (12).$$

Equation (21) indicates that the optimal export subsidy is positive which implies that the export subsidy can raise the national welfare. As c_s <o in general (c_s < o if the demand is linear), the optimal export subsidy tends to aggravate the technology distortion, i.e., the technology choice of the domestic firm is farther away from the cost-minimizing technology level. But this more advanced technology can increase the market share as well as the profits earned from the international market, which definitely makes the country better off. It should be noted that the optimal export subsidy does not move the domestic firm to the Stackelberg leader position in the output space.[3]

Therefore, we can establish:

Proposition 2. *The domestic country has a unilateral incentive to offer an export subsidy to the domestic firm. However, the optimal export subsidy aggravates the technology distortion. Moreover, it does not move the domestic firm to the Stackelberg leader position in the output space.*

The ranking between the technology and export subsidies is straightforward. Note that the welfare levels are the same if the subsidy rates are zero (i.e., W(z=0) =W(s=0)). Because the optimal technology subsidy is zero while the optimal export subsidy is positive, we can conclude that the export subsidy is superior to the technology subsidy. Thus, we can further establish:

Proposition 3. *The welfare under optimal technology subsidy is the same as the welfare at zero export subsidy. But, the welfare under optimal export subsidy is necessarily higher than the one under technology subsidy.*

From the above analysis, it is clear that neither technology subsidy nor export subsidy alone can remove the technology distortion. In what follows, we shall assume that the domestic country can impose both technology and export subsidies *simultaneously* and then examine its welfare implication.

V. Simultaneous Policy Implementation

The second-stage technology choice and the third-stage output decision problem can be found in Section II. The first-stage problem is characterized as follows:

$$(22)\ \underset{s,z}{Max} W(s,z) = \pi - sq - zF(c)$$
$$where\ q = q(c,s,c(s,z))\ and\ q^* = q^*(c,s,c(s,z)).$$

The first-order conditions require:

$$(23)\ \frac{\partial W}{\partial s} = \frac{\partial \pi}{\partial c}c_s + \frac{\partial \pi}{\partial s} + \frac{\partial \pi}{\partial q}q_s + \frac{\partial \pi}{\partial q^*}q_s^* - q - s\frac{dq}{ds} - zF_c c_s = 0$$
$$or\ R_{q*}q_s^* - s(q_c c_s + q_s) - zF_c c_s = 0$$

$$(24)\ \frac{\partial w}{\partial z} = \frac{\partial \pi}{\partial c}c_z + \frac{\partial \pi}{\partial z} - s\frac{dq}{dz} - zF_c c_z = 0$$
$$or\ z = \frac{sq_c}{F_c}$$

$$with\ \frac{\partial \pi}{\partial c} = 0\ from\ (15)\ and\ \frac{\partial \pi}{\partial q} = 0\ from\ (12).$$

Solving (23) *and* (24) *simultaneously for s and z yields*:

$$(25-1)\ s = \frac{R_{q*}q_s^*}{q_s} > 0$$
$$(25-2)\ z = \frac{R_{q*}q_s^*}{F_c} < 0$$

Note that the optimal s and 2 derived in this case can not only remove the technology distortion, but also lead the domestic firm to the Stackelberg leader position. The former can be proved by substituting (25-2) into (15)[4] , while the latter by substituting (25-1) into (12).[5] This leads to :

Proposition 4. *If both the technology and the export subsidies are adopted simultaneously, the domestic country can reach its first-best: cost minimization in its technology choice and the*

Stackelherg leader position in the export market.

VI. Sequential Policy Implementation

In Section V, we assume that the government can announce credibly both policies at the same time. The technology subsidy is announced in the first-stage, implemented in the second stage; on the other hand, the export subsidy is announced in the first-stage, but implemented in the third-stage. In this section, we shall examine another possibility: the technology subsidy is announced right before the technology choice and the export subsidy is announced in the stage before the output decision but after the technology decision. Thus, the equilibrium is characterized by a 4-stage game.

The last stage output decision is the same as we derived before. The third-stage optimal export subsidy is solved in Brander-Spencer's (1985) manner:

$$(26)\ \underset{s}{Max}\, W(s) = \pi - sq - zF(c)$$

The first-order condition requires:

$$(27) W_s \equiv \frac{dW}{ds} = \frac{\partial \pi}{\partial q} q_s + \frac{\partial \pi}{\partial q^*} q_s^* + \frac{\partial \pi}{\partial s} - sq_s - q = 0$$

$$or\ s = \frac{R_{q*} q_s^*}{q_s} > 0$$

$$where\ \frac{\partial \pi}{\partial q} = 0\ from\ (12).$$

It is obvious that the optimal export subsidy is to lead the domestic firm to the Stackleberg leader position in the output space.

Note that q=q(c,c*,s) from the 4th stage problem . Then we can evaluate the comparative static effect of c on s:

$$(28) s_c \equiv \frac{ds}{dc} = \frac{-W_{sc}}{W_{ss}} < 0$$

where W_{ss} <0 by the second-order condition and w, = p'q q'. <0

This implies that a higher domestic marginal cost leads to a lower export subsidy. If the marginal cost of the domestic firm is higher, the closer the distance between the current reaction function and the reaction function passing through the Stackelberg leader position, thus the lower the optimal export subsidy.

It warrants mention that q is not a function of z ; hence the technology subsidy gives no direct effect on the optimal choice of s. Using the property of s=s(c) with s <0, we can form the maximization problem for the second stage:

$$(29)\ \underset{c}{\text{Max}}\quad n(c)=R(q,q^*)-cq-F(c)+s\{c)q+zF(c)$$

The first-order condition requires:

$$(30)\ \frac{d\pi}{dc}=\frac{\partial\pi}{\partial q}\frac{\partial q}{\partial c}+\frac{\partial\pi}{\partial q^*}\frac{\partial q^*}{\partial c}+\frac{\partial\pi}{\partial c}=0$$

$$or\quad R_{q^*}\frac{dq^*}{dc}+s_c q+zF_c=q+F_c$$

$$where\ \frac{\partial\pi}{\partial q}=0\ \ from\ (12)\ and\ \frac{dq^*}{dc}=q_c^*+q_s^* s_c$$

Since s_c<0, the export subsidy policy moves the technology equilibrium farther away from the cost-minimizing level. The intuition for this outcome is clear. The higher the output, the more subsidy the firm can receive from the government. Anticipating this opportunity, the domestic firm has an incentive to adopt a more advanced technology.

The comparative static effect of z one is no longer ambiguous as s is not a function of z in the current case. Apparently, we have:

$$(31)\ \frac{dc}{dz}=-\frac{\pi_{cz}}{\pi_{cc}}=-\frac{F_c}{\pi_{cc}}<0$$

Equation (31) tells us that an increase in technology subsidy necessarily reduces the marginal cost of the domestic firm . The higher the value of z, the lower the effective price of technology (which is measured by (l-z)F(c)) paid by the domestic firm, giving the firm an incentive to choose a more advanced and expensive technology.

Finally, we need to solve for the first-stage technology subsidy problem:

(32) $\underset{z}{Max} W(c) = \pi - sq - zF(c)$

The first-order condition requires:

$$(33)\ \frac{dW}{dz} = \frac{\partial \pi}{\partial c} C_z + \frac{\partial \pi}{\partial z} - s_c c_z q - s\frac{dq}{dz} - F - zF_c c_z$$

$$or \quad z = \frac{-s_c q - R_{q*}\dfrac{dq*}{dc}}{F_c} < 0$$

$$where\ \frac{\partial \pi}{\partial c} = 0, \frac{\partial \pi}{\partial z} = F\ and\ s\frac{dq}{dz} = R_{q*}\frac{dq^*}{dz}$$ [6]

Consequently, the optimal technology subsidy is negative (i.e., z<0) as $F_c < 0, s_c < 0, R_{q*} < 0,$ $\frac{dq^*}{dc} > 0$. If substituting(33) into (30), we obtain:

(34) $q + F_c = 0$

As a result, we obtain:

Proposition 5. *In the 4-stage game, the optimal technology subsidy can remove the entire technology distortion, leading the domestic firm to choose the cost-minimizing technology.*

From the above discussion, we know that technology and export subsidies in either the 3-stage or the 4-stage game can lead to the first-best solution. An interesting question naturally arises: Which policy combination requires a higher subsidy expenditure (or cost) ? In order to answer this question, we will rank these two policy combination in the next section.

VII. The Ranking of the Two Policy Combination

Use a subscript 3 to denote variables associated with the 3-stage game and a subscript 4 the 4-stage game. For example, the total government subsidy budget in the 3-stage game is defined as T_3 and that in the 4-stage game as T_4 . Note that given any q and c, the welfare under the 3-stage analysis is the same as the one under the 4-stage analysis, because the value of q^* is also determined by the foreign output reaction function for any given q. Denote the subsidy difference as A which is defined as:

$$
\begin{aligned}
(35)\ \Delta &= T_4 - T_3 \\
&= [sq + zF(c)]_4 - [sq + F(c)]_3 \\
&= [zF(c)]_4 - [zF(c)]_3 \\
&= (z_4 - z_3)F(c)
\end{aligned}
$$

Two notes are warranted here. First, we have z < 0 in both cases. Second, the first-order condition for profit-maximization in the output stage is $\pi_q = R_q - c + s = 0$. either in the 3-or in the 4-stage game. Given the same q and c, the export subsidy required to produce the given q is the same in the two cases.

From (30), we yield:

$$(36)\ z_4 = \frac{q + F_c - R_{q^*}(q_c^* + q_s^* s_c) - s_c q}{F_c}$$

Alternatively, we have from (15):

$$(37)\ z_3 = \frac{q + F_c - R_{q^*} q_c^*}{F_c}$$

Substitute (36) and (37) into (35) to obtain:

$$(35')\ \Delta = \frac{F}{F_c}\left[q + F_c - R_{q^*}(q_c^* + q_s^* s_c) - s_c q - q - F_c + R_{q^*} q_c^*\right]$$

For any given q and c, the subsidy difference reduces to:

$$(35'')\ \Delta = \frac{-Fs_c}{F_c}\left(R_{q^*}q_c^* + q\right) < 0$$

Since the technology subsidy is negative in both cases, equation (35") shows that tax revenue under the 4-stage analysis exceeds the one under the 3-stage analysis. Therefore, we can establish:

Proposition 6. *The tax revenue, required to achieve the cost-minimizing technology level, is higher under the 4-stage game than under the 3-stage game.*

The intuition behind this result is quite straightforward. According to the concept of subgame perfect equilibrium, the domestic firm can foresee the relation between s and c in the 4-stage analysis. The negative sign of s. gives the domestic firm an incentive to choose a more advanced technology (i.e., a lower c) so as to receive more export subsidy from the government. This incentive deviates the firm's optimal technology level farther away from the socially desirable level (i.e., the cost-minimizing technology). It, therefore, requires a higher technology tax to correct this distortion. Given the same equilibrium level of technology , the tax revenue needed to achieve the assigned technology level is higher under the 4-stage game than under the 3-stage game.

VIII. Concluding Remarks

National governments especially in developing countries play a key role in certain international industries, particularly those high technology and high investment industries. By endogenizing the firm's technology choice, this paper has developed a strategic approach to examine the economic effects of technology subsidy and/or export subsidy on the technology and output decisions. The main findings of this paper are briefly summarized as follows:

(1) If the domestic government can prescribe only one policy to improve its competitiveness in the international market, then export subsidy is superior to technology subsidy.
(2) No matter both technology and export subsidies are implemented simultaneouly or sequentially, both policies can lead to the first-best solution: cost minimization in the technology choice and

Stackelberg leader position in the export market.

(3) To reach the cost-minimizing technology level, the tax revenue required is higher under sequential than simultaneous policy implementation.

Our analysis generates at least one important policy implications. We have shown that with export subsidies available, countries would not choose to subsidize technology. Nevertheless, because GATT codes effectively restrict direct export subsidies, we may view the setting in which only technology subsidies are available as the most relevant case.

Footnotes

1.In the spirit ofDeGraba's work (1990), Choi (1995) compared the effects of optimal tariffs on the technology choice of exporters under the discriminatory tariffs regime and the MFN clause. It is shown that a lower marginal cost technology will be chosen in equilibrium under the MFN clause.

2.Under a linear demand, we have:

$$\begin{aligned}\pi_{cs} &= \left(p' q_s + 2p' q_s^*\right) q_c - q_s \\ &= p'\left(\frac{-2p'}{D} + \frac{2p'}{D}\right) q_c - q_s \\ &= -q_s < 0\end{aligned}$$

3.The export subsidy rate has to be at s = $\frac{R_{q^*} q_s^*}{q_s}$ to move the domestic firm to the Stackelberg leader position. See also the proof in footnote 5

4.By substituting (25-2) into (15), we obtain:

$$\begin{aligned}&R_{q^*} q_c^* + zF_c = q + F_c \\ &R_{q^*} q_c^* + \frac{R_{q^*} q_s^*}{F_c} F_c = q + F_c \\ &R_{q^*}\left(q_c^* + q_s^*\right) = q + F_c \\ &\because q_c^* = -q_s^* \quad by\ (11) \\ &\therefore q + F_c = 0\end{aligned}$$

5.Substituting (25-1) into (12) yields:

$$\begin{aligned}&\mathrm{R_q - c + s} \\ &= \mathrm{R_q - c + \frac{R_{q^*} q_s^*}{q_s}} \\ &= \mathrm{R_q + R_{q^*} \frac{dq^*}{dq} - c = 0}\end{aligned}$$

which is the first-order condition were the domestic firm a Stackelberg leader in an output game with no subsidy.

6. $$s\frac{dq}{dz} = R_{q^*}\frac{q_s^*}{q_s}\frac{dq}{dz}$$

$$= R_{q^*}\frac{q_s^*}{q_s}\left(q_c + q_s s_c\right)$$

$$= R_{q^*}\left(-q_s^* + q_s^* s_c\right) \qquad \left(\because q_s = -q_c\right)$$

$$= R_{q^*}\left(q_c^* + q_s^* s_c\right) \qquad \left(\because q_s^* = -q_c^*\right)$$

$$= R_{q^*}\frac{dq^*}{dc} \qquad \left(\because q^* = q^*\left(s(c), c\right)\right)$$

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