Journal of Korea Trade Vol. 24, No. 2, April 2020, 53-67
https://doi.org/10.35611/jkt.2020.24.2.53
ISSN 1229-828X

Strategic Trade Policies under International Process R&D Competition with or without Market Leaders

JKT 24(2)

Received 6 January 2020
Revised 16 March 2020
Accepted 24 April 2020

Il-Seok Yang†
Department of International Trade, Kyonggi University, South Korea

Abstract

Purpose – The purpose of this paper is to study strategic trade policies under international process research and development (R&D) competition with or without market leaders for free trade and a subsidy regime and compare the effects of R&D subsidies and export subsidies on the equilibrium levels of firm profit and social welfare.

Design/methodology – For the analysis, we use previous work by Haaland and Kind (2008) and construct a differentiated goods duopoly model, wherein two firms compete via quantity in a third-country market for free trade and the subsidy regime. We consider simultaneous-move quantity competition when the two firms choose their quantities simultaneously and sequential-move quantity competition when they choose their quantities sequentially. The results are compared to those of Balboa, Daughety and Reinganum (2004), who studied export subsidies.

Findings – The following are the findings. First, the results of firm preference orderings regarding firm position from Dowrick (1986) and Balboa, Daughety and Reinganum (2004) may not hold in our model when the firms' strategies are strategic substitutes under free trade. Second, the preference rankings under Cournot competition for free trade and a subsidy regime are the same as those in the strategic trade policy of export subsidy. Third, except for the cases of too close substitutes and complements, the results of firm and government preferences regarding firm position are different from those of Balboa, Daughety and Reinganum (2004) in that Stackelberg leadership in a subsidy regime is advantageous when the goods are substitutes but is disadvantageous when the goods are complements. Moreover, the equilibrium level of firm profit is the highest in the Cournot-Nash play when the goods are substitutes in a subsidy regime. Fourth, except for the cases of too close substitutes and complements, the results of firms' and their respective governments' trade regime preferences are similar to those of Balboa, Daughety and Reinganum (2004) in that a Stackelberg leader firm and government prefer free trade if the goods are substitutes and prefer a subsidy regime if the goods are complements. Furthermore, a Stackelberg follower firm and government strongly prefer a subsidy regime to free trade.

Originality/value – By analyzing the effects of R&D subsidies and export subsidies in international markets, we can find similarities and differences between them in international markets.

Keywords: Cournot Competition, Free Trade, Process R&D, Stackelberg Competition, Subsidy Regime
JEL Classifications: D43, F12, O32

1. Introduction

After the seminal work of Brander and Spencer (1985), who considered the model wherein governments first choose export subsidies and then firms compete in a third-country market, several related studies have emerged. These studies have mostly extended and generalized the

† **First and Corresponding author:** isyang@kyonggi.ac.kr

model of Brander and Spencer (1985).[1] However, since the World Trade Organization (WTO) strictly disallows direct export subsidies but allows R&D subsidies, by which we can obtain the same outcomes as those from export subsidies, the study of R&D subsidies is likely more valuable.[2]

Recently, Žigić and Maçi (2011) showed that there is a loss in social welfare and that the incentive to invest in R&D changes when a Stackelberg leader firm loses its position. This is because, in reality, a Stackelberg leader firm often does not only choose quantity or price as the first mover but also chooses R&D investments as the first mover.[3] In this paper, we consider a situation in which the Stackelberg leader firm has quantity leadership as well as technological leadership.

The purpose of this paper is to study strategic trade policies under international process R&D competition with or without market leaders for free trade and a subsidy regime and compare the effects of R&D subsidies and export subsidies on the equilibrium levels of firm profit and social welfare. For the analysis, we use previous work by Haaland and Kind (2008) and construct a differentiated goods duopoly model, wherein two firms compete via quantity in a third-country market for free trade and the subsidy regime. We consider simultaneous-move quantity competition when the two firms choose their quantities simultaneously and sequential-move quantity competition when they choose their quantities sequentially. The results are compared to those of Balboa, Daughety and Reinganum (2004), who studied export subsidies.

Some principal results that we found are as follows. First, the results of firm preference orderings regarding firm position from Dowrick (1986), who studied the industrial organization literature and Balboa, Daughety and Reinganum (2004), who analyzed the literature of the strategic trade policy of export subsidy, may not hold in our model when the firms' strategies are strategic substitutes under free trade. Second, the preference rankings under Cournot competition for free trade and the subsidy regime are the same as those in the strategic trade policy of export subsidy. Third, except for the cases of too close substitutes and complements, the results of firms' and governments' preferences regarding firm position are different from those of Balboa, Daughety and Reinganum (2004) in that Stackelberg leadership in the subsidy regime is advantageous when the goods are substitutes but is disadvantageous when the goods are complements. Moreover, the equilibrium level of firm profit is the highest in the Cournot-Nash play when the goods are substitutes in the subsidy regime. Fourth, except for the cases of too close substitutes and complements, the results of the firms' and their respective governments' trade regime preferences are similar to those of Balboa, Daughety and Reinganum (2004) in that a Stackelberg leader firm and the government prefer free trade if the goods are substitutes and prefer a subsidy regime if the goods are complements. Furthermore, a Stackelberg follower firm and the government strongly prefer a subsidy regime to free trade.

We outline the paper as follows. In Section 2, we introduce notation and formulate the basic model. In Section 3, we derive and compare the Cournot and Stackelberg equilibrium values under free trade. In Section 4, we derive and compare the Cournot and Stackelberg equilibrium values under a subsidy regime. Moreover, these results are compared to those

[1] For example, Brainard and Martimort (1997), Brander (1995), Choi Kang-Sik, Lee Dong-Joon and Lim Seon-Young (2017), Cooper and Riezman (1989), Dixit and Kyle (1985), Eaton and Grossman (1986), Horstmann and Markusen (1986), Ishikawa and Lee (1997), Ishikawa and Spencer (1999) and Spencer and Jones (1992).

[2] See Spencer and Brander (1983).

[3] Žigić and Maçi considered the software industry as an example. See Etro (2004/2006/2007/2008) for more details.

under free trade. Section 5 examines the effect of the trade regime on firm and government preferences regarding firm position and the effect of market structure on firms' and governments' trade regime preferences. Section 6 concludes the paper.

2. The Basic Model

We employ a model in which two firms, Firm 1 and 2, produce a differentiated good and Firm 1 (Firm 2) is located in and owned by residents of Country 1 (Country 2). The two firms export all their outputs to a third-country market and, thus, they engage in competition in the market.[4] It is assumed that the population size in a third country is one and that there is a representative consumer in a third country with quasi-linear preferences that can be specified using a quadratic utility function:

$$U(x_i, x_j) = x_i + x_j - \frac{x_i^2}{2} - \frac{x_j^2}{2} - \gamma x_i x_j \text{ , } i, j = 1,2 \text{ and } i \neq j \text{ ,} \tag{1}$$

where x_i (x_j) is the consumption of firm *i*'s (*j*'s) differentiated good in the third-country market and the parameter $\gamma \in (-1,1)$ stands for a measure of the degree of horizontal differentiation between goods. If γ is positive, zero, or negative, the goods are substitutes, independent, or complements, respectively.

p_i (p_j) is represented as the price of good *i* (good *j*). Then, we express consumer surplus in the third country as $CS = U - p_i x_i - p_j x_j$, $i, j = 1,2$ and $i \neq j$. Given that the two firms export their outputs to the third-country market, we can derive the inverse demand functions by the consumer's optimal choice, $\frac{\partial CS}{\partial x_i} = \frac{\partial CS}{\partial x_j} = 0$, $i, j = 1,2$ and $i \neq j$. The inverse demand functions derived are as follows:

$$p_i = 1 - x_i - \gamma x_j \text{ , } i, j = 1,2 \text{ and } i \neq j \text{ .}^{5} \tag{2}$$

The marginal cost of production for firm *i* without R&D investments is equal to *c*, which is less than one.[6] In this case, the profit margin on firm *i*'s export is given by $(p_i - c)$. However, when firm *i* invests in R&D, it can curtail its marginal cost to $(c - d_i)$ by investing d_i^2 in process innovation.[7] Thus, firm *i*'s marginal cost of production relies on its own R&D investment:

$$MC_i = c - d_i \text{ , } i, j = 1,2 \text{ ,} \tag{3}$$

where d_i (d_j) is firm *i*'s (*j*'s) R&D investment and *c* is large enough, such that MC_i is positive.

---

[4] Consumer surplus in each country is not considered with this assumption. We focus on firm profit and social welfare.

[5] The direct demand functions are $x_i = \frac{1 - \gamma - p_i + \gamma p_j}{1 - \gamma^2}$, $i, j = 1,2$ and $i \neq j$.

[6] We need this condition for positive output including a case of a monopoly.

[7] The cost of R&D is represented by a quadratic function which reflects the existence of diminishing returns to R&D expenditures. See D'Aspremont and Jacquemin (1988) and Haaland and Kind (2008) for more details.

The profit function of firm *i* can be written as

$$\pi_i = \left[p_i - (c - d_i) \right] x_i - d_i^2 + s_i d_i \ , \ i, j = 1,2 \ , \tag{4}$$

where s_i is the level of per-unit R&D subsidy that firm *i* obtains from its domestic government.[8]

The welfare of country *i* is given by the profit of its own firm minus R&D subsidies:

$$W_i = \pi_i - s_i d_i \ , \ i, j = 1,2 \ . \tag{5}$$

The game form is as follows. At stage one, each government simultaneously sets R&D subsidy or tax levels to maximize its country's respective social welfare. If firm 1 and 2 move sequentially in a game, at stage two, exporting firm *j* chooses its R&D level and quantity, and at stage three, the exporting firm *i* chooses its R&D level and quantity. On the other hand, if firm 1 and 2 move simultaneously, at stage two, exporting firm *i* chooses its R&D level and quantity to maximize its profit.

3. Free Trade under Simultaneous-Move and Sequential-move Quantity Competition

In this section, we present the solutions of Cournot and Stackelberg competition under free trade. In this case, free trade implies that two governments commit not to step into the market by agreeing to a free trade agreement to remove trade barriers among member countries.[9] Unlike Balboa, Daughety and Reinganum (2004), who considered the potential effect of a government subsidy policy without the firms' R&D investment, we include R&D decisions of the firms in our model. We consider the two cases in which the firms located in their respective countries simultaneously choose the levels of their R&D investment and quantity to maximize their respective profit in the first case and, in the second case, firm *j* chooses the levels of its R&D investment and quantity, followed by firm *i*.

3.1. Free Trade under Simultaneous-move Quantity Competition

We first consider Cournot competition under free trade. Setting $s_1 = s_2 = 0$, the profits for firm *i* with Equation (2) are given by $\pi_i(d_i, x_i, x_j) = (1 - x_i - \gamma x_j - c + d_i) x_i - d_i^2$, $i = 1,2$. Firm *i*'s best response functions are given by

$$d_i = \frac{x_i}{2} \tag{6}$$

$$x_i = \frac{1 - c + d_i - \gamma x_j}{2} \ .[10] \tag{7}$$

[8] The R&D subsidy trade policy of governments could prevent trade partners from fair and efficient competition in the market. Spencer and Brander (1983) call this the "business stealing effect," which is interesting in international trade literature, compared to the case of firms' own R&D investment only.

[9] See Choi Kang-Sik, Lee Ki-Dong and Lim Seon-Young (2016).

[10] Firm *i*'s second-order conditions are satisfied: $\frac{\partial^2 \pi_i}{\partial d_i^2} = -2 < 0$, $\frac{\partial^2 \pi_i}{\partial x_i^2} = -2 < 0$.

After we solve the system of the four best response functions, we obtain the following equilibrium values: $\tilde{d}_i^C = \tilde{d}_j^C = \frac{1-c}{3+2\gamma}$, $\tilde{x}_i^C = \tilde{x}_j^C = \frac{2(1-c)}{3+2\gamma}$, $\tilde{p}_i^C = \tilde{p}_j^C = c + \frac{1-c}{3+2\gamma}$, $\tilde{\pi}_i^C = \tilde{\pi}_j^C = \tilde{W}_i^C = \tilde{W}_j^C = \frac{3(1-c)^2}{(3+2\gamma)^2}$, where the superscript *C* represents Cournot competition and '~' represents the equilibrium under free trade.

3.2. Free Trade under Sequential-move Quantity Competition

We now consider Stackelberg competition in which firm *j* moves first as a Stackelberg leader and firm *i* moves second as a Stackelberg follower under free trade. The profit for firm *i* with Equation (2) is given by $\pi_i(d_i, x_i, x_j) = (1 - x_i - \gamma x_j - c + d_i)x_i - d_i^2$ and firm *i*'s best response functions are the same as in Equations (6) and (7). Inserting Equation (6) into Equation (7) yields

$$x_i = \frac{2(1 - c - \gamma x_j)}{3}. \tag{8}$$

Putting Equation (8) into $\pi_j(d_j, x_j, x_i) = (1 - x_j - \gamma x_i - c + d_j)x_j - d_j^2$ yields $\pi_j(d_j, x_j) = \left\{1 - x_j - \gamma\left[\frac{2(1-c-\gamma x_j)}{3}\right] - c + d_j\right\}x_j - d_j^2$. Firm *j*'s best response functions are given by

$$d_j = \frac{x_j}{2} \tag{9}$$

$$x_j = \frac{(3-2\gamma)(1-c) + 3d_j}{2(3-2\gamma^2)}.^{11} \tag{10}$$

Solving Equations (9) and (10) simultaneously yields the following equations:

$$\tilde{d}_j^L = \frac{(3-2\gamma)(1-c)}{9-8\gamma^2} \tag{11}$$

$$\tilde{x}_j^L = \frac{2(3-2\gamma)(1-c)}{9-8\gamma^2}, \tag{12}$$

where the superscript *L* denotes the Stackelberg leader.

Incorporating Equations (11) and (12) into Equations (8) and (6) yields the following equations:

$$\tilde{d}_i^F = \frac{(9-6\gamma-4\gamma^2)(1-c)}{3(9-8\gamma^2)} \tag{13}$$

$$\tilde{x}_i^F = \frac{2(9-6\gamma-4\gamma^2)(1-c)}{3(9-8\gamma^2)}, \tag{14}$$

---

[11] Firm *j*'s second-order conditions are satisfied: $\frac{\partial^2 \pi_j}{\partial d_j^2} = -2 < 0$, $\frac{\partial^2 \pi_j}{\partial x_j^2} = -\frac{2(3-2\gamma^2)}{3} < 0$.

where the superscript *F* represents the Stackelberg follower.

Inserting for Equations (11), (12), (13), and (14) into Equations (2), (4) with $s_1 = s_2 = 0$, and Equation (5) yields

$$\tilde{p}_i^F = c + \frac{(9-6\gamma-4\gamma^2)(1-c)}{3(9-8\gamma^2)}, \quad \tilde{p}_j^L = c + \frac{(3-2\gamma)(3-4\gamma^2)(1-c)}{3(9-8\gamma^2)}, \quad \tilde{\pi}_i^F = \tilde{W}_i^F = \frac{(9-6\gamma-4\gamma^2)^2(1-c)^2}{3(9-8\gamma^2)^2},$$

$$\tilde{\pi}_j^L = \tilde{W}_j^L = \frac{(3-2\gamma)^2(1-c)^2}{3(9-8\gamma^2)}.$$

Under free trade, we can compare the equilibrium levels of firm profit and social welfare under the Cournot competition in place with those under the Stackelberg competition. The results derived are summarized in the following proposition:

Proposition 1: Suppose that both a home and a foreign firm that invest in process R&D compete with quantity in a third-country market under free trade. Then, under the simultaneous-move and sequential-move quantity competition, $\tilde{\pi}_i^L > \tilde{\pi}_i^C > \tilde{\pi}_i^F$ and $\tilde{W}_i^L > \tilde{W}_i^C > \tilde{W}_i^F$ if the goods are substitutes and not too close, $\tilde{\pi}_i^L > \tilde{\pi}_i^F > \tilde{\pi}_i^C$ and $\tilde{W}_i^L > \tilde{W}_i^F > \tilde{W}_i^C$ if the goods are substitutes and too close, and $\tilde{\pi}_i^F > \tilde{\pi}_i^L > \tilde{\pi}_i^C$ and $\tilde{W}_i^F > \tilde{W}_i^L > \tilde{W}_i^C$ if the goods are complements.[12]

Proposition 1 can be explained as follows. Even though we use linear demand and constant marginal costs, R&D complicates the analysis under free trade, compared to the case of quantity competition without export subsidy. In the case of R&D, the convexity of the R&D cost function leads to a nonmonotonic comparison of the three cases. It even becomes intense when the goods are too close substitutes. Thus, in the case of R&D, we must consider the cases of too close substitutes and not too close substitutes, separately.

Gal-Or (1985) showed that Stackelberg leadership was advantageous if the firms' strategies were strategic substitutes and disadvantageous if the firms' strategies were strategic complements.[13] This relationship holds for our model. Dowrick (1986) included Cournot competition and showed that the equilibrium level of firm profit is the highest when a firm is a Stackelberg leader, the second-highest when a firm is a Cournot-Nash player, and the lowest when a firm is a Stackelberg follower if the firms' strategies are strategic substitutes. On the other hand, if the firms' strategies are strategic complements, Dowrick adds that the equilibrium level of firm profit is the highest when a firm is a Stackelberg follower, the second-highest when a firm is a Stackelberg leader, and the lowest when a firm is a Cournot-Nash player. This relationship holds for our model when the firms' strategies are strategic complements but may not hold when the firms' strategies are strategic substitutes.

4. Subsidy Regime under Simultaneous-move and Sequential-Move Quantity Competition

In this section, we present the solutions of Cournot and Stackelberg competition under a

[12] Here, too close substitutes and too close complements mean that $0.9 < \gamma < 1$ and $-1 < \gamma < -0.9$, respectively.

[13] When the firms compete with quantity and the goods are substitutes, it is a case of strategic substitutes. However, when the firms compete with quantity and the goods are complements, it is a case of strategic complements.

subsidy regime. We consider the two cases. In the first case, the governments simultaneously set R&D subsidy or tax levels to maximize their respective social welfare at the first stage and then firms simultaneously choose their respective R&D levels and quantity to maximize their respective profits at the second stage. In the second case, each government simultaneously sets R&D subsidy or tax levels to maximize its respective social welfare at the first stage and then the firms move sequentially. Firm *j* chooses its R&D level and quantity at the second stage, then, firm *i* chooses its R&D level and quantity to maximize its respective profit at the third stage.

4.1. Subsidy Regime under Simultaneous-move Quantity Competition

We first consider Cournot competition, with arbitrary subsidy rates, s_i , $i=1,2$. The profits for firm *i* with Equation (2) are given by $\pi_i(d_i,x_i,x_j;s_i)=(1-x_i-\gamma x_j-c+d_i)x_i-d_i^2+s_i d_i$. Firm *i*'s best response functions are given by

$$d_i=\frac{x_i+s_i}{2} \tag{15}$$

$$x_i=\frac{1-c+d_i-\gamma x_j}{2}.^{14} \tag{16}$$

After we solve the system of the four best response functions, we get the following equilibrium levels of firm profit and social welfare as a function of s_i and s_j :

$$\pi_i^C=\pi_i\left[d_i^C(s_i,s_j),\, x_i^C(s_i,s_j),\, x_j^C(s_i,s_j);\, s_i\right],\ i,j=1,2 \text{ and } i\neq j \tag{17}$$

$$W_i^C(s_i,s_j)=\pi_i\left[d_i^C(s_i,s_j),\, x_i^C(s_i,s_j),\, x_j^C(s_i,s_j);\, s_i\right]-s_i d_i^C(s_i,s_j),\ i,j=1,2 \text{ and } i\neq j, \tag{18}$$

Next, we differentiate Equation (18) with respect to s_i , $i=1,2$, and solving the two equations derived simultaneously yields

$$s_i^C=\frac{2\gamma^2(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)}\geq 0,\ i=1,2\ . \tag{19}$$

The equilibrium level of R&D subsidy is positive, except in the case of independent goods. This implies that each government subsidizes when the firms compete with quantity and the goods are substitutes or complements. These equilibrium levels of R&D subsidies lead to the following equilibrium values:

$$d_i^C=d_j^C=\frac{3(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)}\ ,\quad x_i^C=x_j^C=\frac{2(3-\gamma^2)(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)}\ ,\quad p_i^C=p_j^C=c+\frac{(3-2\gamma^2)(1-c)}{9+2\gamma(1-\gamma)(3+\gamma)}\ ,$$

$$\pi_i^C=\pi_j^C=\frac{(27-18\gamma^2+4\gamma^4)(1-c)^2}{\left[9+2\gamma(1-\gamma)(3+\gamma)\right]^2},\ W_i^C=W_j^C=\frac{(3-2\gamma^2)(9-2\gamma^2)(1-c)^2}{\left[9+2\gamma(1-\gamma)(3+\gamma)\right]^2}\ .$$

---

[14] Firm *i*'s second-order conditions are satisfied: $\frac{\partial^2\pi_i}{\partial d_i^2}=-2<0$, $\frac{\partial^2\pi_i}{\partial x_i^2}=-2<0$.

Under Cournot competition, we can compare the equilibrium levels of firm profit and social welfare under free trade in place with those under the subsidy regime. The results derived are summarized in Proposition 2.

Proposition 2: Suppose that both a home and a foreign firm that invest in process R&D compete with quantity in a third-country market under free trade and the subsidy regime. Then, under simultaneous-move quantity competition, $W_i^C < \tilde{W}_i^C$ ($W_i^C > \tilde{W}_i^C$) in the case of substitutes (complements). However, $\pi_i^C > \tilde{\pi}_i^C$ regardless of the nature of the goods.

Proposition 2 can be explained as follows. Even though R&D complicates the analysis, a comparison of the results from the R&D subsidy and export subsidy under free trade and the subsidy regime yields the same conclusion when the firms engage in Cournot competition. This implies that the R&D subsidy and export subsidy in Cournot competition affect the results from the analysis under free trade and the subsidy regime in the same direction when we compare the two cases and the convexity of the R&D cost function does not matter in this analysis.

Proposition 2 shows that the preference rankings under the international process R&D competition in our setting are the same as those derived in the strategic trade policy of export subsidy literature.

4.2. Subsidy Regime under Sequential-move Quantity Competition

We now turn to Stackelberg competition in which firm *j* moves first as a Stackelberg leader and firm *i* moves second as a Stackelberg follower, with arbitrary subsidy rates, s_i, $i = 1, 2$. The profit for firm *i* with Equation (2) is given by $\pi_i(d_i, x_i, x_j; s_i) = (1 - x_i - \gamma x_j - c + d_i)x_i - d_i^2 + s_i d_i$ and firm *i*'s best response functions are the same as Equations (15) and (16). Inserting Equation (15) into Equation (16) yields

$$x_i = \frac{2(1 - c - \gamma x_j) + s_i}{3}. \tag{20}$$

Putting Equation (20) into $\pi_j(d_j, x_j, x_i; s_j) = (1 - x_j - \gamma x_i - c + d_j)x_j - d_j^2 + s_j d_j$ yields $\pi_j(d_j, x_j; s_j, s_i) = \left\{1 - x_j - \gamma\left[\frac{2(1 - c - \gamma x_j) + s_i}{3}\right] - c + d_j\right\}x_j - d_j^2 + s_j d_j$. Firm *j*'s best response functions are given by

$$d_j = \frac{x_j + s_j}{2} \tag{21}$$

$$x_j = \frac{(3 - 2\gamma)(1 - c) + 3d_j - \gamma s_i}{2(3 - 2\gamma^2)}.^{15} \tag{22}$$

Solving Equations (21) and (22) simultaneously yields the following equations:

---

[15] Firm *j*'s second-order conditions are satisfied: $\frac{\partial^2 \pi_j}{\partial d_j^2} = -2 < 0$, $\frac{\partial^2 \pi_j}{\partial x_j^2} = -\frac{2(3 - 2\gamma^2)}{3} < 0$.

$$d_j^L = \frac{(3-2\gamma)(1-c)+2(3-2\gamma^2)s_j-\gamma s_i}{9-8\gamma^2} \tag{23}$$

$$x_j^L = \frac{2(3-2\gamma)(1-c)+3s_j-2\gamma s_i}{9-8\gamma^2}\ . \tag{24}$$

Incorporating Equations (23) and (24) into Equations (20) and (15) yields the following:

$$d_i^F = \frac{(9-6\gamma-4\gamma^2)(1-c)+2(9-7\gamma^2)s_i-3\gamma s_j}{3(9-8\gamma^2)} \tag{25}$$

$$x_i^F = \frac{2(9-6\gamma-4\gamma^2)(1-c)+(9-4\gamma^2)s_i-6\gamma s_j}{3(9-8\gamma^2)}\ . \tag{26}$$

From Equations (23), (24), (25), and (26), we obtain the following equilibrium levels of firm profit and social welfare as a function of s_i and s_j :

$$\pi_i^F = \pi_i\left[d_i^F(s_i,s_j),\ x_i^F(s_i,s_j),\ x_j^L(s_i,s_j);\ s_i\right] \tag{27}$$

$$\pi_j^L = \pi_j\left[d_j^L(s_i,s_j),\ x_j^L(s_i,s_j),\ x_i^F(s_i,s_j);\ s_j\right] \tag{28}$$

$$W_i^F(s_i,s_j) = \pi_i\left[d_i^F(s_i,s_j),\ x_i^F(s_i,s_j),\ x_j^L(s_i,s_j);\ s_i\right] - s_i d_i^F(s_i,s_j) \tag{29}$$

$$W_j^L(s_i,s_j) = \pi_j\left[d_j^L(s_i,s_j),\ x_j^L(s_i,s_j),\ x_i^F(s_i,s_j);\ s_j\right] - s_j d_j^L(s_i,s_j)\ . \tag{30}$$

Next, we differentiate Equations (29) and (30) with respect to s_i and s_j , respectively, and solving the two best response functions derived simultaneously yields

$$s_j^L = 0 \tag{31}$$

$$s_i^F = \frac{2\gamma^2(9-6\gamma-4\gamma^2)(1-c)}{3(3-2\gamma^2)(9-10\gamma^2)}\ . \tag{32}$$

The equilibrium level of R&D subsidy or tax is zero when a domestic firm is a Stackelberg leader. The explanation is as follows. Government *j*'s payoff is given by $W_j^L(s_i,s_j) = \pi_j\left[d_j^L(s_i,s_j),\ x_j^L(s_i,s_j),\ x_i^F\left(x_j^L(s_i,s_j),s_i\right);\ s_j\right] - s_j d_j^L(s_i,s_j)$, which depends on s_j both directly and indirectly through $x_j^L(s_i,s_j)$. Furthermore, firm *i*'s best response function relies on x_j and s_i , but not directly on s_j . Thus, government *j* can affect firm *i* only indirectly through x_j^L , which influences firm *i*'s best response function. Firm *j* already considers this effect of x_j^L on firm *i*'s best response function and government *j* cannot do anything more. This result is similar to the case of the strategic trade policy of export subsidy analyzed by Balboa, Daughety and Reinganum (2004). However, the equilibrium level of R&D subsidy can be positive or negative when a domestic firm is a Stackelberg follower.[16]

[16] The equilibrium level of R&D subsidy is positive in almost all areas. However, when the goods are too close substitutes or complements, it can be negative.

This result is different from the case of export subsidy analyzed by Balboa, Daughety and Reinganum (2004), who show $s_i^F > 0$. These equilibrium levels of R&D subsidies lead to the following equilibrium values:

$$d_i^F = \frac{(9-4\gamma^2)(9-6\gamma-4\gamma^2)(1-c)}{9(3-2\gamma^2)(9-10\gamma^2)},\ d_j^L = \frac{(27-18\gamma-24\gamma^2+14\gamma^3)(1-c)}{3(3-2\gamma^2)(9-10\gamma^2)},\ x_i^F = \frac{2(9-7\gamma^2)(9-6\gamma-4\gamma^2)(1-c)}{9(3-2\gamma^2)(9-10\gamma^2)},$$

$$x_j^L = \frac{2(27-18\gamma-24\gamma^2+14\gamma^3)(1-c)}{3(3-2\gamma^2)(9-10\gamma^2)},\ p_i^F = c + \frac{(9-6\gamma-4\gamma^2)(1-c)}{9(3-2\gamma^2)},\ p_j^L = c + \frac{(3-4\gamma^2)(27-18\gamma-24\gamma^2+14\gamma^3)(1-c)}{9(3-2\gamma^2)(9-10\gamma^2)},$$

$$\pi_i^F = \frac{(9-6\gamma-4\gamma^2)^2(81-126\gamma^2+52\gamma^4)(1-c)^2}{27(3-2\gamma^2)^2(9-10\gamma^2)^2},\quad \pi_j^L = \frac{(9-8\gamma^2)(27-18\gamma-24\gamma^2+14\gamma^3)^2(1-c)^2}{27(3-2\gamma^2)^2(9-10\gamma^2)^2},$$

$$W_i^F = \frac{(9-6\gamma-4\gamma^2)^2(1-c)^2}{9(3-2\gamma^2)(9-10\gamma^2)},\ W_j^L = \frac{(9-8\gamma^2)(27-18\gamma-24\gamma^2+14\gamma^3)^2(1-c)^2}{27(3-2\gamma^2)^2(9-10\gamma^2)^2}.$$

Some calculations show that, in the subsidy regime, the Stackelberg leader produces more than the Stackelberg follower does, except in the cases of too close substitutes and complements and of independent goods. Moreover, the Stackelberg leader invests in R&D more than the Stackelberg follower does when the goods are substitutes and vice versa when goods are complements, except in the cases of too close substitutes and complements and of independent goods. These results are contrary to the case under free trade, in which the Stackelberg leader produces more than the Stackelberg follower does, except in the case of independent goods, and the Stackelberg leader invests in R&D more than the Stackelberg follower does, except in the case of independent goods. Further, we can compare these results with the case of export subsidy analyzed by Balboa, Daughety and Reinganum (2004). While the two different models have the same result in that the Stackelberg leader produces more than the Stackelberg follower does under free trade in both models, they have a different result in that the Stackelberg leader produces less than the Stackelberg follower does in the subsidy regime of Balboa, Daughety and Reinganum (2004). However, the Stackelberg leader produces more than the Stackelberg follower does, except in the cases of too close substitutes and complements, in this model.

Under the subsidy regime, we can compare the equilibrium levels of firm profit and social welfare under Cournot competition in place with those under Stackelberg competition. The results derived are summarized in the following proposition:

Proposition 3: Suppose that both a home and a foreign firm that invest in process R&D compete with quantity in a third-country market when each government provides R&D subsidy or tax to each firm. Then, under simultaneous-move and sequential-move quantity competition, except for too close substitutes and complements, $\pi_i^C > \pi_i^L > \pi_i^F$ if the goods are substitutes, $\pi_i^F > \pi_i^C > \pi_i^L$ if the goods are complements and not so close, and $\pi_i^F > \pi_i^L > \pi_i^C$ if the goods are complements and somewhat close. Moreover, except for too close substitutes and complements, $W_i^L > W_i^C > W_i^F$ if the goods are substitutes and $W_i^F > W_i^L > W_i^C$ if the goods are complements.

Proposition 3 can be explained as follows. Even though we use linear demand and constant marginal costs, R&D and R&D subsidy complicate the analysis, compared to the case of export subsidy. In the case of R&D subsidy, the convexity of the R&D cost function leads to a nonmonotonic comparison of the three cases. It even becomes intense when the goods are too close substitutes and complements. Thus, in the case of R&D subsidy, we must consider the cases of too close substitutes, not-too-close substitutes, too close complements, and not-

too-close complements, separately. Further, in the case of R&D subsidy, the results from the comparison of the three cases are quite different from those of the case of export subsidy. This implies that R&D subsidy affects the results from the analysis under the subsidy regime in a different direction than export subsidy when we compare the three cases.

In the cases of too close substitutes and complements, the results are so complicated that we rule out them. For firms' and governments' preferences regarding firm position, we find that Stackelberg leadership is advantageous when the goods are substitutes but is disadvantageous when the goods are complements in the subsidy regime. Moreover, the equilibrium level of firm profit is the highest in the Cournot-Nash play when the goods are substitutes in the subsidy regime. These results are different from those of Balboa, Daughety and Reinganum (2004) who show that, for firm preferences regarding firm position, Stackelberg leadership is always disadvantageous and the Cournot-Nash profit is always between those of the Stackelberg leader and follower in the subsidy regime and, for government preferences regarding firm position, the Stackelberg leader is advantageous when the goods are complements and is disadvantageous when the goods are substitutes.

Under Stackelberg competition, we can compare the equilibrium levels of firm profit and social welfare under free trade in place with those under the subsidy regime. The results derived are summarized in Proposition 4:

Proposition 4: Suppose that both a home and a foreign firm that invest in process R&D compete with quantity in a third-country market under free trade and the subsidy regime. Then, under sequential-move quantity competition, except for too close substitutes and complements, $\pi_i^L < \tilde{\pi}_i^L$ and $W_i^L < \tilde{W}_i^L$ ($\pi_i^L > \tilde{\pi}_i^L$ and $W_i^L > \tilde{W}_i^L$) when the goods are substitutes (complements). However, except for too close substitutes and complements, $\pi_i^F > \tilde{\pi}_i^F$ and $W_i^F > \tilde{W}_i^F$ regardless of the nature of the goods.

Proposition 4 can be explained as follows. Even though R&D and R&D subsidy complicate the analysis, a comparison of the results from R&D subsidy and export subsidy under free trade and the subsidy regime yields the same conclusion when the firms engage in Stackelberg competition, except in the cases of too close substitutes and complements. In the case of R&D subsidy, the convexity of the R&D cost function leads to a nonmonotonic comparison of the two cases. It even becomes intense when the goods are too close substitutes and complements. This implies that R&D subsidy and export subsidy in Stackelberg competition affect the results from the analysis under free trade and the subsidy regime in the same direction, except in the cases of too close substitutes and complements, when we compare the two cases.

For the same reason mentioned earlier, we exclude the cases of too close substitutes and complements. For firms' and their respective governments' trade regime preferences, we find that a Stackelberg leader firm and government prefer free trade if the goods are substitutes and prefer a subsidy regime if the goods are complements. However, a Stackelberg follower firm and government strongly prefer a subsidy regime to free trade. These results are similar to those of Balboa, Daughety and Reinganum (2004), who study export subsidy.

5. Firm and Government Preferences Regarding Firm Position and Government Policies

We now assemble the results derived in Sections 3 and 4 and make two tables. They show that the effects of free trade and subsidy regime on firms' and governments' preferences regarding firm position and simultaneous-move and sequential-move market structure on

firms' and governments' preferences regarding free trade and subsidy regime.

Table 1 summarizes firms' and governments' preference orderings of firm position, excluding the cases of too close substitutes and complements. Since we cannot have the explicit results from the following comparisons with the cases of too close substitutes and complements, those cases are excluded. The trade regimes are stated in the top row and the nature of the goods on the left-hand column.

Table 1. Effect of trade regime on firms' and governments' preferences regarding firm position, excluding the cases of too close substitutes and complements

	Free trade	**Subsidy regime**
Substitutes, $0<\gamma\leq 0.9$	$\tilde{\pi}_i^L > \tilde{\pi}_i^C > \tilde{\pi}_i^F$ $\tilde{W}_i^L > \tilde{W}_i^C > \tilde{W}_i^F$	$\pi_i^C > \pi_i^L > \pi_i^F$ $W_i^L > W_i^C > W_i^F$
Complements and not so close, $-0.76\leq\gamma<0$	$\tilde{\pi}_i^F > \tilde{\pi}_i^L > \tilde{\pi}_i^C$ $\tilde{W}_i^F > \tilde{W}_i^L > \tilde{W}_i^C$	$\pi_i^F > \pi_i^C > \pi_i^L$ $W_i^F > W_i^L > W_i^C$
Complements and somewhat close, $-0.9\leq\gamma\leq-0.77$		$\pi_i^F > \pi_i^L > \pi_i^C$ $W_i^F > W_i^L > W_i^C$

Under free trade, we find that the firms and their governments have the same preferences since they have the same payoffs. When the goods are substitutes and not too close, the equilibrium level of firm profit is the highest when a firm is a Stackelberg leader, the second-highest when a firm is a Cournot-Nash player, and the lowest when a firm is a Stackelberg follower.[17] When the goods are complements, the equilibrium level of firm profit is the highest when a firm is a Stackelberg follower, the second-highest when a firm is a Stackelberg leader, and the lowest when a firm is a Cournot-Nash player. This is the basic preference ordering found in the industrial organization and the strategic trade policy of export subsidy literature.

Under a subsidy regime, we find that the government preferences are the same as under free trade, irrespective of the nature of the goods. However, the firms' preferences regarding position can change. For substitutes and not too close, the equilibrium level of firm profit is the highest when a firm is a Cournot-Nash player, the second-highest when a firm is a Stackelberg leader, and the lowest when a firm is a Stackelberg follower. In this case, the firms and their governments disagree in their preferences concerning the firm's position. For complements and not so close, the equilibrium level of firm profit is the highest when a firm is a Stackelberg follower, the second-highest when a firm is a Cournot-Nash player, and the lowest when a firm is a Stackelberg leader. In this case, the firms and their governments also disagree in their preferences regarding the firm's position. On the other hand, for complements and somewhat but not too close, firms' preferences are the same as under free trade. In this case, the firms and their governments continue to agree in their preferences concerning the firm's position.

Table 2 summarizes firms' and governments' trade regime preferences, excluding the cases of too close substitutes and complements. The cases of too close substitutes and complements are excluded for the reason explained earlier. The market structures are stated in the top row and the nature of the goods is in the left column.

[17] In fact, $\tilde{\pi}_i^L > \tilde{\pi}_i^F > \tilde{\pi}_i^C$ and $\tilde{W}_i^L > \tilde{W}_i^F > \tilde{W}_i^C$ when the goods are too close substitutes, for example, $\gamma = 0.99$.

Table 2. Effect of market structure on firms' and governments' trade regime preferences, excluding the cases of too close substitutes and complements

	Simultaneous-move	**Sequential-move**
Substitutes, $0<\gamma\leq 0.9$	$\pi_i^C > \tilde{\pi}_i^C$ $W_i^C < \tilde{W}_i^C$	$\pi_i^L < \tilde{\pi}_i^L$ $\pi_i^F > \tilde{\pi}_i^F$ $W_i^L < \tilde{W}_i^L$ $W_i^F > \tilde{W}_i^F$
Complements, $-0.9\leq\gamma<0$	$\pi_i^C > \tilde{\pi}_i^C$ $W_i^C > \tilde{W}_i^C$	$\pi_i^L > \tilde{\pi}_i^L$ $\pi_i^F > \tilde{\pi}_i^F$ $W_i^L > \tilde{W}_i^L$ $W_i^F > \tilde{W}_i^F$

Under a Cournot-Nash market structure, we get the same results as those in the strategic trade policy of export subsidy literature. The equilibrium level of firm profit under a subsidy regime is always greater than that under free trade. Furthermore, the equilibrium level of welfare under free trade is greater than that under a subsidy regime if the goods are substitutes and vice versa if the goods are complements. Therefore, the firms and their governments disagree about the trade regime for substitutes, with the firms preferring a subsidy regime and the governments preferring free trade. However, they agree on the trade regime for complements, with both the firms and the governments preferring a subsidy regime.

Under a Stackelberg market structure, we also obtain the same results as those in the strategic trade policy of export subsidy literature, except in the cases of too close substitutes and complements. We find that the firms and their respective governments will always be in agreement about the trade regime. If the goods are substitutes and not too close, the equilibrium levels of firm profit and welfare for a Stackelberg leader are higher under free trade than under a subsidy regime while the equilibrium levels of firm profit and welfare for a Stackelberg follower are higher under a subsidy regime than under free trade. In this case, the two governments disagree on the trade regime. If the goods are complements and not too close, the equilibrium levels of firm profit and welfare for the Stackelberg leader and follower are higher under a subsidy regime than under free trade. In this case, the two governments agree on the trade regime as they do under a Cournot-Nash market structure.

Further, since the government of the Stackelberg leader firm has the optimal strategies that provide zero subsidy in both trade regimes, offering zero subsidy is dominant strategies in both trade regimes. Therefore, in trying to sustaining free trade, it does not use a strategy of turning to the subsidy regime in order to punish the government of the follower firm.

One important observation is that a trade policy by the government can be decided both by the market structure and by the nature of the goods. For substitutes and simultaneous timing, both governments will participate in free trade supported by trigger strategies.[18] For substitutes and sequential timing, the governments will not agree on the trade regime, thus, each government will subsidize its respective firm. For complements, the governments have

[18] In this case, the firms and their respective governments will not agree on the trade regime, with the firms preferring a subsidy regime and the governments preferring free trade. The governments could solve this problem using trigger strategies since each government can give the other government a punishment by turning to the subsidy regime. See Balboa, Daughety and Reinganum (2004).

the same preferences for the subsidy regime in the two market structures. This result is the same as that of the strategic trade policy of export subsidy in Balboa, Daughety and Reinganum (2004), except in the cases of too close substitutes and complements.[19]

6. Concluding Remarks

We have explored the relationship between the market structure and trade regime in a differentiated goods duopoly model wherein each government sets a level of R&D subsidy or tax for its firm in the first stage and then each firm chooses its R&D investment and quantity, either simultaneously or sequentially, under a subsidy regime and only includes the game without the first stage mentioned above under free trade. Comparing the results to those of Balboa, Daughety and Reinganum (2004) who examined the strategic trade policy of export subsidy, we found some important similarities and differences between R&D subsidies and export subsidies. There are similar results between them. Except for the cases of too close substitutes and complements, the results of firms' and their respective governments' trade regime preferences are the same in both subsidies. However, excluding the cases of too close substitutes and complements, the results of firm and government preferences regarding firm position are different in both subsidies.

This paper can be extended in several ways. First, we can study price competition as well as quantity competition. Adding price competition will make our analysis richer and help us find more meaningful results. Second, we can consider the endogenous choice of competition mode, in which each firm decides whether to adopt the quantity or price contract as a strategic variable before the governments' decision on tax/subsidy. This will help us gain a better understanding of how the competition mode is endogenously determined.[20] These extensions of the paper are worth studying.

References

Balboa, O. I., A. F. Daughety and J. F. Reinganum (2004), "Market Structure and the Demand for Free Trade", *Journal of Economics & Management Strategy*, 13(1), 125-150.

Brainard, L. and D. Martimort (1997), "Strategic Trade Policy with Incompletely Informed Policymakers", *Journal of International Economics*, 42, 33-65.

Brander, J. A. (1995), "Strategic Trade Policy". In G. Grossman and K. Rogoff (Eds.), *Handbook of International Economics* (Vol. 3), Amsterdam: North-Holland, 1395-1455.

Brander, J. A. and B. J. Spencer (1985), "Export Subsidies and International Market Share Rivalry", *Journal of International Economics*, 18, 83-100.

Choi, Kang-Sik, Ki-Dong Lee and Seon-Young Lim (2016), "Strategic Trade Policies in International Rivalry when Competition Mode is Endogenous", *Hitotsubashi Journal of Economics*, 57, 223-241.

[19] We can consider the endogenous role choice game in which a firm has an option to lead or declines that option before the governments' decision on subsidies, as in Balboa, Daughety and Reinganum (2004). Without analysis, it is certain that we have the same result as that of Balboa, Daughety and Reinganum (2004), except in the cases of too close substitutes and complements, since the results in Table 2 are the same as those of Balboa, Daughety and Reinganum (2004), except in the said cases.

[20] Choi Kang-Sik, Lee Dong-Joon and Lim Seon-Young (2016) and Choi Kang-Sik and Lim Seon-Young (2018) study strategic export tax/subsidy policies with the endogenous choice of competition mode, while the latter is examined under vertical structures.

Choi, Kang-Sik, Dong-Joon Lee and Seon-Young Lim (2017), "Strategic Trade Policies with First-Mover and Second-Mover Advantages in a Vertical Structure", *Journal of International Trade & Economic Development*, 26(5), 612-632.

Choi, Kang-Sik and Seon-Young Lim (2018), "A Reappraisal of Strategic Trade Policies with the Endogenous Mode of Competition under Vertical Structures", *Journal of International Trade & Economic Development*, 28(1), 11-29.

Cooper, R. and R. Riezman (1989), "Uncertainty and the Choice of Trade Policy in Oligopolistic Industries", *Review of Economic Studies*, 56, 129-140.

D'Aspremont, C. and A. Jacquemin (1988), "Cooperative and Noncooperative R&D in Duopoly with Spillovers", *American Economic Review*, 78(5), 1133-1137.

Dixit, A. K. and A. S. Kyle (1985), "The Use of Protection and Subsidies for Entry Promotion and Deterrence", *American Economic Review*, 75, 139-152.

Dowrick, S. (1986), "Von Stackelberg and Cournot Duopoly: Choosing Roles", *RAND Journal of Economics*, 17, 251-260.

Eaton, J. and G. M. Grossman (1986), "Optimal Trade and Industrial Policy under Oligopoly", *Quarterly Journal of Economics*, 101(2), 383-406.

Etro, F. (2004), "Innovation by Leaders", *Economic Journal*, 114(495), 281-303.

Etro, F. (2006), "Aggressive Leaders", *RAND Journal of Economics*, 37(1), 146-154.

Etro, F. (2007), *Competition, Innovation and Antitrust: A Theory of Market Leaders and its Policy Implications*, Berlin: Springer Verlag.

Etro, F. (2008), "Stackelberg Competition with Endogenous Entry", *Economic Journal*, 118(532), 1670-1697.

Gal-Or, E. (1985), "First Mover and Second Mover Advantages", *International Economic Review*, 26, 649-653.

Haaland, J. I. and H. J. Kind (2008), "R&D Policies, Trade and Process Innovation", *Journal of International Economics*, 74, 170-187.

Horstmann, I. J. and J. R. Markusen (1986), "Up the Average Cost Curve: Inefficient Entry and the New Protectionism", *Journal of International Economics*, 20, 225-247.

Ishikawa, J. and Ki-Dong Lee (1997), "Backfiring Tariffs in Vertically Related Markets", *Journal of International Economics*, 42, 395-423.

Ishikawa, J. and B. J. Spencer (1999), "Rent-Shifting Export Subsidies with an Imported Intermediate Product", *Journal of International Economics*, 48, 199-232.

Spencer, B. J. and J. A. Brander (1983), "International R&D Rivalry and Industrial Strategy", *Review of Economic Studies*, 50(4), 546-554.

Spencer, B. J. and R. W. Jones (1992), "Trade and Protection in Vertically Related Markets", *Journal of International Economics*, 32, 31-55.

Žigić, K. and I. Maçi (2011), "Competition Policy and Market Leaders", *Economic Modelling*, 28, 1042-1049.