The effects of export subsidies on welfare and quality of goods

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December 3, 2015

Abstract. Firms may compete not only on outputs and prices, but also on R&D investments before their supply of commodities. In this paper we address, in a third market model of international trade, the effects of subsidies on welfare as well as quality of goods under alternative forms of competition (Cournot and Bertrand) and alternative policy regimes (free trade and export subsidies). The main findings of this paper are as follows. (1) Subsidies decrease not only outputs and world welfare but also R&D in the Bertrand case, but increase them in the Cournot case. That is, introduction of export subsidies makes Cournot firms produce more in higher quality goods but makes Bertrand firms produce less in lower quality goods. (2) Although the Bertrand equilibrium is more efficient under free trade than the Cournot equilibrium, the Cournot equilibrium is more efficient than the Bertrand equilibrium in a sequential equilibrium with export subsidies and R&D investment.

JEL classification: L13, D43, F12, F12
Keywords: Product R&D; Price versus quantity competition; Welfare; Export subsidy

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Acknowledgments: I would like to thank Eric Bond, Fumio Dei, Naoto Jinji, Kazuo Nishimura, Masao Oda, Akihiko Yanase and Makoto Yano for their helpful suggestions. I also benefited from a presentation at the IEFS Japan Annual Meeting held in April 2009 (Kyoto University).

1. Introduction

Recently, governments in many countries have tended to support their domestic firms financially though various policy instruments that seem to be hidden forms of export subsidies. In the strategic trade policy literature, production or export subsidies may change real marginal production costs and thus affect firms' decisions on outputs and prices.[1] Conventional wisdom on this issue is as follows. Brander and Spencer (1985) constructed a third market international duopoly model, consisting of

1） For a review of trade theory in an imperfect competition, see, for example, Brander（1995）and Wong（1995）.

two exporting countries and one importing country. One firm in each exporting country produces a (nationally differentiated) product and exports it to the importing country's domestic market in Cournot fashion in the second stage. There is no consumption of these goods in the exporting countries, and no firm that produces those goods exists in the importing country. The government of each exporting country maximizes its national welfare (net profit of the subsidy) through an export subsidy in the first stage. Under this model, Brander and Spencer (1985) obtained that unilateral intervention by one exporting country leads to a subsidy for export under Cournot competition. Furthermore, under Cournot competition, bilateral subsidy intervention by two symmetric exporting countries leads to higher outputs, importing country welfare, profits for the exporting countries and world welfare, but lower prices and welfare for the two exporting countries. On the other hand, Eaton and Grossman (1986) showed that unilateral intervention by one exporting country leads to a tax under Bertrand competition. Under Bertrand competition, bilateral subsidy intervention by two symmetric exporting countries leads to lower outputs, importing country welfare, profits for the exporting countries and world welfare, but higher prices and welfare for the two exporting countries.

In actuality, firms compete not only on outputs and prices, but also on R&D investments and such things as capacity or location, prior to their supply of commodities.

In this paper, we reexamine the effects of export subsidies in a third market international duopoly model using a three-stage game, with export subsidies in the second stage and investments for quality improvement (product R&D) in the first stage, unlike the process R&D analyzed by Spencer and Brander (1983) where a government can credibly commit itself to subsidies for export and R&D before the R&D decisions are made by private firms. In our scenario, firms can make commitments to governments in advance.

The reason we adopt this scenario is that R&D, like any form of investment, is likely to be chosen before production takes place, so R&D is likely to be chosen before policies such as export subsidies that are intended to affect output. Thus, we can analyze the case where the choice of R&D influences the government's optimal export subsidy and forward-looking firms will exploit this fact.[2)] This aspect is often dismissed in the standard theory of strategic trade policy where firms play after governments. The importance of the order of decisions is discussed, for example, by Neary (1991) in a two-stage game and by Choi (1995) and Leahy and Neary (1996) in three- and four-stage games.

Our definition is that the Cournot equilibrium is more efficient than the Bertrand equilibrium when world welfare is higher in the Cournot equilibrium than in the Bertrand equilibrium.

The main findings of this paper are as follows. (1) Export subsidies decrease not only outputs and world welfare, but also R&D in the Bertrand case but increase them in the Cournot case. That is, an introduction of export subsidies makes Cournot firms produce more in higher quality goods but makes Bertrand firms produce less in lower quality goods. (2) Although under free trade the Bertrand

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2) See Leahy and Neary (1996).

equilibrium is more efficient than the Cournot equilibrium, the Cournot equilibrium is more efficient than the Bertrand equilibrium in a sequential equilibrium with an export subsidy and R&D investment.[3)]

The remainder of this paper is organized as follows. In Section 2, a basic model is presented that augments the Symeonidis (2003) model by including export subsidies. Section 3 deals with the Cournot equilibrium, characterizing the results without subsidies and those with subsidies. Section 4 discusses a case for Bertrand competition. In Section 5 we compare the level of quality, outputs and welfare in Cournot competition under free trade and subsidies with those in the case of the Bertrand competition under free trade and subsidies, and derive several implications from this comparison. Section 6 provides a summary and conclusion.

2. Basic model

We consider a three-country model consisting of two exporting countries and one importing (home) country. One firm in each exporting country produces a nationally differentiated product and exports to the importing country's domestic market in duopolistic fashion. There is no consumption of these goods in the exporting countries, and no firm that produces those goods exists in the importing country. Each firm chooses a variety u_i described by a vertical characteristic called quality. Quality is assumed to increase the consumer's willingness to pay for the firm's various products, but R&D expenditure is needed to improve quality, and quality cannot be changed as quickly as price or quantity choices.[4)] The government of each exporting country maximizes its national welfare (net profit of the subsidy) through an export subsidy.

The importing country's household utility function is:

$$U(x_1, x_2) = x_1 + x_2 - \frac{x_1^2}{u_1^2} - \frac{x_2^2}{u_2^2} - \frac{\sigma x_1}{u_1}\frac{x_2}{u_2} + M, \quad \sigma > 0, \quad 4 - \sigma^2 > 0,$$

where x_i and u_i are the quantity and the quality of the i-th good, respectively, and M denotes consumption expenditure on outside goods. This is a quality-augmented version of the standard quadratic utility function proposed by Sutton (1998), with σ denoting an inverse measure of the degree of horizontal product differentiation. From the first-order condition for utility maximization by a household, we obtain the linear inverse demand functions:

3) Which is more efficient, Cournot competition or Bertrand competition? It is widely believed that Bertrand competition is more efficient than Cournot competition. For example, Singh and Vives (1984) discuss the superiority of Bertrand competition in a horizontally differentiated duopoly model. For the case of an oligopoly refer, for example, to Vives (1985) and Hackner (2000). However, this standard view has been challenged by a number of theoretical models. To demonstrate cases of the superiority of the Cournot equilibrium over the Bertrand equilibrium, Qiu (1997) and Symeonidis (2003) introduce strong cross-firm spillover effects (externalities) of R&D in a two-stage differentiated duopoly model, with the R&D investment stage occurring prior to the production stage. In this paper, we will address this issue, focusing especially on an open economy trade policy.

4) See Symeonidis (2003).

$$p_i(x, u) = 1 - \frac{2x_i}{u_i^2} - \frac{\sigma x_j}{u_i u_j}, \quad i, j = 1, 2, \quad i \neq j, \tag{1}$$

where $x = (x_i, x_j)$, $u = (u_i, u_j)$, and p_i denotes the product prices. We can rewrite these as ordinary demand functions as follows:

$$x_i(p, u) = \frac{2(1 - p_i)u_i^2 - \sigma(1 - p_j)u_i u_j}{4 - \sigma^2}; \quad i, j = 1, 2, \quad i \neq j, \tag{2}$$

where $p = (p_i, p_j)$. Equations (1) and (2) imply that for substitute goods, the equilibrium x_i is decreasing in p_i and increasing in p_j . It is also increasing in u_i and decreasing in u_j . Similarly, the equilibrium price p_i is increasing in u_i and decreasing in u_j . This nice property holds under Cournot competition as well as Bertrand competition (see x_i^Q, x_i^P , p_i^Q and p_i^P below).[5] Define the consumer's surplus as $CS = U - (p_1 x_1 + p_2 x_2 + M)$, and let c be the constant marginal cost of the two exporting countries 'firms. Then the gross or market profit for each firm is $\pi_i = (p_i - c + e_i)\, x_i$, where e_i denotes an export subsidy to the i-th firm provided by the exporting country's government.[6] Improvement in quality requires investment expenditures R_i, which are linked to u_i by $R_i\,(u_i) = u_i^4$. Hence the net or overall profit can be written as:

$$\Pi_i = \pi_i - R_i = (p_i - c + e_i)x_i - u_i^4, \qquad i = 1, 2. \tag{3}$$

The welfare of the importing country W_h, that of the i-th exporting country W_i and the world welfare W may be summarized as:

$$W_h = CS, \quad W_i = \Pi_i - e_i x_i, \quad \text{and} \quad W = W_h + W_1 + W_2. \tag{4}$$

The game considered here has the following three stages. At stage 1, each firm simultaneously chooses an R&D investment level $R_i(u_i)$ to maximize its net profit Π_i. At stage 2, the government of each exporting country simultaneously chooses an export subsidy to maximize its welfare W_i, or commits itself to zero subsidy under free trade. At stage 3, product market competition takes place. A symmetric sub-game perfect equilibrium is obtained by a process of backward induction.

3. Cournot competition

In this section, Cournot competition is considered in reverse order.

3.1 The third stage: Determination of production and prices

Firms choose outputs to maximize net profits Π_i, given export subsidies e_i and R&D investment level $R_i(u_i)$. Solving the output reaction functions for Cournot-Nash outputs yields

5) Let $p_i^* = u_i p_i$ and $x_i^* = x_i/u_i$. Then equations (1) and (2) can be rewritten as $p_i^* = u_i - 2x_i^* - \sigma x_j^*$ and $x_i^* = \frac{2(u_i - p_i^*) - \sigma(u_j - p_j^*)}{4 - \sigma^2}$, respectively, which displays some nice properties of this model.

6) In this paper we often call e_i an export subsidy, but it can be a production subsidy or other forms of financial supports for production.

$$x_i^Q(\overset{+}{e_i}, \overset{-}{e_j}, \overset{+}{u_i}, \overset{-}{u_j}) = \frac{\{4(1-c+e_i)u_i - (1-c+e_j)\sigma u_j\}u_i}{16-\sigma^2}, \quad \Pi_i^Q(e,u) = \frac{2[x_i^Q]^2}{u_i^2} - R_i, \tag{5}$$

$$p_i^Q(\overset{-}{e_i}, \overset{-}{e_j}, \overset{+}{u_i}, \overset{-}{u_j}) = c + \frac{2(1-c)(4u_i - \sigma u_j) - (8-\sigma^2)e_i u_i - 2\sigma e_j u_j}{u_i(16-\sigma^2)},$$

where $e = (e_i, e_j)$ and the superscript Q denotes the third stage Cournot competition equilibrium. The positive or negative above each variable indicate the sign of the partial derivative under $\sigma > 0$.

3.2 The second stage: Determination of an export subsidy

Considering the third-stage competition, and taking investments in the first stage and the foreign subsidy as given, the government of an exporting country chooses an export subsidy (tax, if negative), so as to maximize its national welfare, $W_i^Q = \Pi_i^Q - e_i x_i^Q$. Solving the policy reaction functions simultaneously for e_i gives the second stage export subsidy as

$$e_i^{QN}(\overset{+}{u_i}, \overset{-}{u_j}) = \frac{(1-c)\{(16-\sigma^2)u_i - 4\sigma u_j\}\sigma^2}{\Delta_N u_i} > 0, \tag{6}$$

where $\Delta_N = \Delta_1\Delta_2 = (16-4\sigma-\sigma^2)(16+4\sigma-\sigma^2) > 0$, and the superscript QN denotes the second stage Nash export subsidy equilibrium under Cournot competition. Substituting e_i^{QN} gives the second stage equilibrium outputs, prices, profits and welfare of each exporting country:

$$x_i^{QN} = \frac{4(1-c)\{(16-\sigma^2)u_i - 4\sigma u_j\}u_i}{\Delta_N},$$

$$p_i^{QN} = c + \frac{(1-c)\{(16-\sigma^2)u_i - 4\sigma u_j\}(8-\sigma^2)}{\Delta_N u_i},$$

$$\Pi_i^{QN} = \pi_i^{QN} - R_i = \frac{2[x_i^{QN}]^2}{u_i^2} - R_i \quad \text{and} \quad W_i^{QN} = \frac{8-\sigma^2}{8}\pi_i^{QN} - R_i.$$

3.3 The endogenous determination of quality level: R&D investment and effects of subsidies

In the first stage of R&D competition, each firm chooses its R&D (quality) level u_i independently to maximize its net profit. Consider first the case of free trade ($e = 0$). Maximizing $\Pi_i^Q(0, u)$ in (5) with respect to u_i, and solving the reaction functions simultaneously for u_1 and u_2, gives:

Lemma 1. (Cournot equilibrium under free trade: CF). For $0 < \sigma < 2$, the symmetric Cournot equilibrium values for qualities, outputs, prices, national welfare and world welfare under free trade are:

$$u_i^{CF} = \frac{2(1-c)}{4+\sigma}\sqrt{\frac{1}{4-\sigma}} > 0, \qquad x_i^{CF} = \frac{4(1-c)^3}{(4+\sigma)^3(4-\sigma)} > 0,$$

$$p_i^{CF} = c + \frac{2(1-c)}{4+\sigma} > 0, \qquad W_h^{CF} = \frac{4(1-c)^4(2+\sigma)}{(4+\sigma)^4(4-\sigma)} > 0,$$

$$\Pi_i^{CF} = W_i^{CF} = \frac{8(1-c)^4(2-\sigma)}{(4-\sigma)^2(4+\sigma)^4} > 0 \quad \text{and} \quad W^{CF} = \frac{4(1-c)^4(16-2\sigma-\sigma^2)}{(4-\sigma)^2(4+\sigma)^4} > 0,$$

where the upper limits for σ reflect the second-order and the stability conditions.
Proof. See Symeonidis (2003).

Next, consider the subsidy case. Maximizing $\Pi_i^{QN}(u) = \pi_i^{QN}(u) - R_i(u_i)$ with respect to u_i, and solving the reaction functions

$$\frac{\partial \Pi_i^{QN}}{\partial u_i} = \frac{64(1-c)^2(16-\sigma^2)\{(16-\sigma^2)u_i - 4\sigma u_j\}}{\Delta_N^2} - 4u_i^3 = 0\,,$$

simultaneously for u_1 and u_2 gives:

Lemma 2. (Cournot equilibrium under Nash subsidies: CN). For $0 < \sigma \leq 1.65$, the symmetric Cournot equilibrium values for qualities, export subsidies, outputs, prices, national welfare and world welfare are:

$$u_i^{CN} = \frac{4(1-c)}{\Delta_2}\sqrt{\frac{(16-\sigma^2)}{\Delta_1}} > 0, \qquad e_i^{CN} = \frac{(1-c)\sigma^2}{\Delta_2} > 0,$$

$$x_i^{CN} = \frac{64(1-c)^3(16-\sigma^2)}{\Delta_1\Delta_2^3} > 0, \qquad p_i^{CN} = c + \frac{(1-c)(8-\sigma^2)}{\Delta_2} > 0,$$

$$W_h^{CN} = \frac{256(1-c)^4(2+\sigma)(16-\sigma^2)}{\Delta_1\Delta_2^4} > 0,$$

$$\Pi_i^{CN} = \frac{256(1-c)^4(16-8\sigma-\sigma^2)(16-\sigma^2)}{\Delta_1^2\Delta_2^4} > 0,$$

$$W_i^{CN} = \frac{64(1-c)^4(\sigma^4+4\sigma^3-20\sigma^2-32\sigma+64)(16-\sigma^2)}{\Delta_1^2\Delta_2^4} > 0, \quad \text{for} \quad 0 < \sigma \leq 1.3,$$

and

$$W^{CN} = \frac{128(1-c)^4(64+24\sigma-4\sigma^2-\sigma^3)(16-\sigma^2)}{\Delta_1^2\Delta_2^4} > 0.$$

4. Bertrand competition

Let us now go on to Bertrand competition.

4.1 The third stage: Determination of production and prices

Each firm chooses a price to maximize net profits Π_i, given the export subsidies and R&D investment levels. The resulting Bertrand-Nash prices and profits are:

$$p_i^P(\overset{-}{e_i}, \overset{-}{e_j}, \overset{+}{u_i}, \overset{-}{u_j}) = c + \frac{(1-c)\{(8-\sigma^2)u_i - 2\sigma u_j\} - 8e_i u_i - 2\sigma e_j u_j}{(16-\sigma^2)u_i}, \tag{7}$$

$$x_i^P(\overset{+}{e_i}, \overset{-}{e_j}, \overset{+}{u_i}, \overset{-}{u_j}) = \frac{2\{(8-\sigma^2)(1-c+e_i)u_i - 2(1-c+e_j)\sigma u_j\}u_i}{(4-\sigma^2)(16-\sigma^2)},$$

$$\Pi_i^P(e, u) = \frac{2(p_i^P - c + e_i)^2 u_i^2}{4-\sigma^2} - R_i, \tag{8}$$

where the superscript P denotes the third stage Bertrand competition equilibrium.

4.2 The second stage: Determination of an export subsidy or tax

In the second stage, the government of an exporting country chooses an export subsidy (tax, if negative), so as to maximize the welfare, $W_i^P = \Pi_i^P - e_i x_i^P$. Solving the reaction functions simultaneously for e_i gives the second stage export subsidy as

$$e_i^{PN}(\overset{-}{u_i}, \overset{+}{u_j}) = -\frac{(1-c)\{2(16-3\sigma^2)u_i - (8-\sigma^2)\sigma u_j\}\sigma^2}{2\Delta_N u_i} < 0. \tag{9}$$

Substituting e_i^{PN} i gives the equilibrium prices, outputs, profits and welfare of each exporting country:

$$p_i^{PN} = c + \frac{4(1-c)\{2(16-3\sigma^2)u_i - (8-\sigma^2)\sigma u_j\}}{\Delta_N u_i},$$

$$x_i^{PN} = \frac{(1-c)\{2(16-3\sigma^2)u_i - (8-\sigma^2)\sigma u_j\}(8-\sigma^2)u_i}{(4-\sigma^2)\Delta_N}, \tag{10}$$

and

$$\Pi_i^{PN} = \pi_i^{PN} - R_i = \frac{(8-\sigma^2)^2 u_i^2}{32(4-\sigma^2)}(p_i^{PN} - c)^2 - R_i, \quad W_i^{PN} = \frac{8}{8-\sigma^2}\pi_i^{PN} - R_i. \tag{11}$$

4.3 The endogenous determination of quality level: R&D investment and effects of subsidies

Consider Bertrand competition under free trade. Maximizing (8) with respect to u_i at $e = 0$, and solving the reaction functions simultaneously for u_1 and u_2 gives:

Lemma 3 (Bertrand equilibrium under free trade: BF). For $0 < \sigma \leq 1.46$, the symmetric Bertrand equilibrium values for qualities, outputs, prices, net national welfare and net world welfare under free trade are:

$$u_i^{BF} = \frac{(1-c)}{(4-\sigma)}\sqrt{\frac{8-\sigma^2}{(4+\sigma)(2+\sigma)}} > 0, \qquad x_i^{BF} = \frac{2(1-c)^3(8-\sigma^2)}{(4+\sigma)(2+\sigma)^2(4-\sigma)^3} > 0,$$

$$p_i^{BF} = c + \frac{(1-c)(2-\sigma)}{4-\sigma} > 0, \qquad W_h^{BF} = \frac{4(1-c)^4(8-\sigma^2)}{(4+\sigma)(2+\sigma)^2(4-\sigma)^4} > 0,$$

$$\Pi_i^{BF} = W_i^{BF} = \frac{(1-c)^4(8-4\sigma-\sigma^2)(8-\sigma^2)}{(4+\sigma)^2(2+\sigma)^2(4-\sigma)^4} > 0,$$

and

$$W^{BF} = \frac{2(1-c)^4(16-2\sigma-\sigma^2)(8-\sigma^2)}{(4+\sigma)^2(2+\sigma)^2(4-\sigma)^4} > 0.$$

Proof. See Symeonidis (2003).

Next consider Bertrand competition under subsidies. Maximizing (11) with respect to u_i, and solving the reaction functions

$$\frac{\partial \Pi_i^{PN}}{\partial u_i} = \frac{2(1-c)(8-\sigma^2)^2(16-3\sigma^2)\{2(16-3\sigma^2)u_i-(8-\sigma^2)\sigma u_j\}}{(4-\sigma^2)\Delta_N^2} - 4u_i^3 = 0$$

simultaneously for u_1 and u_2, gives:

Lemma 4 (Bertrand equilibrium under Nash subsidies: BN). Under $0 < \sigma \leq 1.56$, the symmetric Bertrand equilibrium values for qualities, export subsidies, prices, outputs, net national welfare and net world welfare are:

$$u_i^{BN} = \frac{(1-c)(8-\sigma^2)}{\Delta_1}\sqrt{\frac{(16-3\sigma^2)}{2(2+\sigma)\Delta_2}} > 0, \qquad e_i^{BN} = -\frac{(1-c)(2-\sigma)\sigma^2}{2\Delta_1} < 0,$$

$$p_i^{BN} = c + \frac{4(1-c)(2-\sigma)}{\Delta_1} > 0, \qquad x_i^{BN} = \frac{(1-c)^3(16-3\sigma^2)(8-\sigma^2)^3}{2(2+\sigma)^2\Delta_1^3\Delta_2^2} > 0,$$

$$W_h^{BN} = \frac{(1-c)^4(16-3\sigma^2)(8-\sigma^2)^4}{2(2+\sigma)^2\Delta_1^4\Delta_2} > 0,$$

$$\Pi_i^{BN} = \frac{(1-c)^4(4-\sigma-\sigma^2)(4-\sigma)(16-3\sigma^2)(8-\sigma^2)^4}{4(2+\sigma)^2\Delta_1^4\Delta_2^2} > 0,$$

$$W_i^{BN} = \frac{(1-c)^4(128-64\sigma-8\sigma^2+8\sigma^3-3\sigma^4)(16-3\sigma^2)(8-\sigma^2)^3}{4(2+\sigma)^2\Delta_1^4\Delta_2^2} > 0,$$

and

$$W^{BN} = \frac{(1-c)^4(128-16\sigma-16\sigma^2+2\sigma^3-\sigma^4)(16-3\sigma^2)(8-\sigma^2)^3}{(2+\sigma)^2\Delta_1^4\Delta_2^2} > 0.$$

5. Comparisons and discussions

We are now in a position to compare Cournot competition and Bertrand competition and to derive the relative efficiency between them. We define efficiency as follows:

Definition. The Cournot equilibrium is more efficient than the Bertrand equilibrium when world welfare (the total welfare) is higher in the Cournot equilibrium, even if the welfare of each exporting country is higher in the Bertrand equilibrium, and vice versa.

Referring to the preceding Lemmas, the ranking of qualities and outputs, as well as that of the following welfare, can be demonstrated by simple calculations. Thus we obtain the following theorem.

Theorem 1. Under $0 < \sigma \leq 1.46$,

$$\text{(a):} \quad u_i^{BN} < u_i^{BF} < u_i^{CF} < u_i^{CN} < u_i^{W} = \frac{(1-c)}{2\sqrt{(2+\sigma)}}, \tag{12}$$

$$\text{(b):} \quad x_i^{BN} < x_i^{CF} < x_i^{BF} < x_i^{CN} < x_i^{W} = \frac{(1-c)^3}{4(2+\sigma)^3}, \tag{13}$$

(c): $p_i^{BF} < p_i^{BN} < p_i^{CN} < p_i^{CF}$, (d): $W_h^{BN} < W_h^{CF} < W_h^{BF} < W_h^{CN}$,

(e-1): for $0 < \sigma \leq 1.24$, $W_i^{CN} < W_i^{BF} < W_i^{CF} < W_i^{BN}$,

(e-2): for $1.25 \leq \sigma \leq 1.46$, $W_i^{CN} < W_i^{BF} < W_i^{BN} < W_i^{CF}$,

(f): $\Pi_i^{BN} < \Pi_i^{BF} < \Pi_i^{CF} < \Pi_i^{CN}$, and (g): $W^{BN} < W^{CF} < W^{BF} < W^{CN}$,

where the superscript W for u_i and x_i denotes the first best solution regarding maximizing net world welfare.

From Theorem 1, we can derive the following four results, three of which are extensions of well-known results.

Proposition 1. (Extended Brander and Spencer) Under Cournot competition, bilateral subsidy intervention by two symmetric exporting countries increases not only outputs, importing country welfare and world welfare, but also R&D investments.

Proposition 2. (Extended Eaton and Grossman) Under Bertrand competition, bilateral subsidy intervention by two symmetric exporting countries decreases not only outputs, importing country welfare and world welfare, but also R&D investments.

That is, introducing export subsidies makes Cournot firms produce more in higher quality goods but makes Bertrand firms produce less in lower quality goods.

Proposition 3. (Symeonidis) If there is no intervention and no spillover effects from R&D investments, then while Cournot firms invest more in R&D, Bertrand firms still have higher outputs and charge lower prices. Furthermore, the welfare of the importing country (the consumer's surplus) and the world welfare (the total welfare) are higher, and the welfare in each exporting country (the net profit) is lower in the Bertrand equilibrium.

To demonstrate cases of the superiority of the Cournot equilibrium over the Bertrand equilibrium in a closed economy model, Qiu (1997) and Symeonidis (2003) introduced the strong cross-firm spillover effect (externalities) of R&D. However, in the next proposition we show that even without spillover effects, the Cournot equilibrium can be more efficient than the Bertrand equilibrium in sequential equilibria with an export subsidy and R&D investment.

Proposition 4. (Reversal for outputs and welfare) Under subsidy: (1) although Cournot firms produce and supply more than Bertrand firms do, they charge higher prices; (2) the welfare of the importing country (the consumer's surplus) and the world welfare (the total welfare) are higher in the Cournot equilibrium than in the Bertrand equilibrium, and the welfare of exporting countries is higher in the Bertrand equilibrium.

Although Proposition 3 states that the outputs, the welfare of the importing country and the world welfare are higher in the Bertrand equilibrium under free trade, Proposition 4 states the opposite under subsidies. Why does a reversal of outputs and welfare ranking occur? The difference between Cournot investment and Bertrand investment can be higher under the export subsidy-tax scheme than under free trade as shown in (12)[7].

This in turn increases Cournot outputs and decreases Bertrand outputs. The ranking of the outputs in (13) can be explained as follows. With higher investments, Cournot outputs under the export subsidy-tax scheme become larger not only than under free trade, but also than the free trade level of Bertrand outputs. On the other hand, Bertrand outputs under the subsidy-tax scheme become smaller than the free trade level of Cournot outputs.

The reasons that the difference between Cournot investment and Bertrand investment increases under the export subsidy-tax scheme can be found by comparing the incentive for R&D investments for both types of firm. With the help of (5) and (6), and using the inverse demand functions $p_i(x, u)$ and Cournot outputs $x_i^Q(e, u)$, the gross profit of the Cournot firm becomes $\pi_i = \{p_i(x^Q(e, u),u) - c + e_i\}x_i^Q(e, u) = \pi_i(x^Q(e, u), e_i, u)$, where $e_i = e_i^{QN}(u)$. Then, for given u_j, u_i has direct positive effects and indirect

7) Symeonidis (2003) showed not only that R&D are expenditures higher in the Cournot equilibrium than in the Bertrand equilibrium, but also that the difference between the two increases as R&D spillovers become stronger or as goods become less differentiated. By contrast, although spillover effects are significant phenomena, we assume that there are none in this paper.

strategic effects on the profit π_i. Total differentiation with respect to u_i, holding u_j constant, yields the total change in gross profit, evaluated with the Nash export subsidies as:

$$\frac{d\pi_i}{du_i} = \frac{\partial\pi_i}{\partial x_j}\left[\frac{\partial x_j^Q}{\partial e_i}\frac{\partial e_i^{QN}}{\partial u_i} + \frac{\partial x_j^Q}{\partial e_j}\frac{\partial e_j^{QN}}{\partial u_i} + \frac{\partial x_j^Q}{\partial u_i}\right] + \frac{\partial\pi_i}{\partial e_i}\frac{\partial e_i^{QN}}{\partial u_i} + \frac{\partial\pi_i}{\partial u_i}.$$

Rearranging the terms, we have:

$$\frac{d\pi_i}{du_i} = \underbrace{\frac{\partial\pi_i}{\partial x_j}\left[\frac{\partial x_j^Q}{\partial e_i}\frac{\partial e_i^{QN}}{\partial u_i} + \frac{\partial x_j^Q}{\partial e_j}\frac{\partial e_j^{QN}}{\partial u_i}\right]}_{(+)} + \underbrace{x_i\frac{\partial e_i^{QN}}{\partial u_i}}_{(+)} + \underbrace{x_i\frac{\partial p_i}{\partial u_i}}_{(+)} + \underbrace{\frac{\partial\pi_i}{\partial x_j}\frac{\partial x_j^Q}{\partial u_i}}_{(+)}. \tag{14}$$

Next, given the ordinal demand functions $x_i(p, u)$ and the Bertrand prices $p_i^P(e, u)$ and applying (7) and (9), the gross profit of the Bertrand firm will be $\pi_i = \{p_i^P(e, u) - c + e_i\}x_i(p^P(e, u), u) = \pi_i(p^P(e, u), e_i, u)$, where $e = e^{PN}(u)$. Total differentiation with respect to u_i, holding u_j constant and rearranging terms, yields the total change in gross profit, evaluated under Nash export subsidies as:

$$\frac{d\pi_i}{du_i} = \frac{\partial\pi_i}{\partial p_j}\left[\frac{\partial p_j^P}{\partial e_i}\frac{\partial e_i^{PN}}{\partial u_i} + \frac{\partial p_j^P}{\partial e_j}\frac{\partial e_j^{PN}}{\partial u_i} + \frac{\partial p_j^P}{\partial u_i}\right] + \frac{\partial\pi_i}{\partial e_i}\frac{\partial e_i^{PN}}{\partial u_i} + \frac{\partial\pi_i}{\partial u_i}.$$

Again rearranging the terms, we have:

$$\frac{d\pi_i}{du_i} = \underbrace{\frac{\partial\pi_i}{\partial p_j}\left[\frac{\partial p_j^P}{\partial e_i}\frac{\partial e_i^{PN}}{\partial u_i} + \frac{\partial p_j^P}{\partial e_j}\frac{\partial e_j^{PN}}{\partial u_i}\right]}_{(-)} + \underbrace{x_i\frac{\partial e_i^{PN}}{\partial u_i}}_{(-)} + \underbrace{(p_i - c + e_i)\frac{\partial x_i}{\partial u_i}}_{(+)} + \underbrace{\frac{\partial\pi_i}{\partial p_j}\frac{\partial p_j^P}{\partial u_i}}_{(-)}. \tag{15}$$

On the right-hand side of the above two equations, (14) and (15), there are four terms that emerge. We first consider the third and fourth terms, which emerge without export subsidies. The third terms are the positive effects that increase the willingness to pay or the quantity demanded. The fourth terms are the positive (negative) strategic effect of R&D investment by firm *i* under Cournot (Bertrand) competition. This implies that a Cournot (Bertrand) firm has an incentive to invest more (less) under free trade.

The other two terms emerge under subsidies. The first terms can be called ‘strategic effects through export subsidies’ and the second terms can be considered to be the volume effect through export subsidies. Both of these terms are positive (negative) under Cournot (Bertrand) competition. Thus, these two terms show that each Cournot (Bertrand) firm has an incentive to increase (decrease) its R&D investment strategically under export subsidies more than under free trade.

6. Summary and conclusion

Firms may compete not only on outputs or prices, but also on R&D investments before their supply of commodities. In this paper, we address the effects of subsidies in the production stage, not only on outputs, prices and welfare, but also on R&D investments under alternative forms of competition (Cournot and Bertrand) and alternative policy regimes (free trade and export subsidies). We analyze a three-stage game with export subsidies in the second stage and investments for quality improvement in the first stage, obtaining the following results. (1) Subsidies decrease not only outputs and world welfare but also R&D in the Bertrand case but increase them in the Cournot case. That is, an introduction of export subsidies makes Cournot firms produce more in higher quality goods but makes Bertrand firms produce less in lower quality goods. (2) Although the Bertrand equilibrium is more efficient than the Cournot equilibrium under free trade, the Cournot equilibrium is more efficient than the Bertrand equilibrium in a sequential equilibrium with an export subsidy and R&D investment.

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