Technological Upgrading under Tariffs and Equivalent Quotas *

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Abstract

This paper sets out to discuss, between tariff and quota polices, which is best able to speed up the process of upgrading the technological standards of firms in importing countries. It is shown that when domestic and foreign firms engage in Cournot quantitative competition, the home firm employs higher technology standards under tariff policy than under the equivalent quota policy. In the case of Bertrand competition with product differentiation, the aforementioned result still holds true, given that the market demands are linear and symmetrical.

Keywords: Tariffs, Quotas, Technological upgrading

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I. Introduction

Since tariffs and quotas are the trade policies most widely adopted by the governments of importing nations, the equivalence of tariffs and quotas has long been an issue of particular interest in international trade theory. Since Bhagwati (1965, 1968) and Shibata (1968) opened up discussion on this subject, many other scholars have contributed to this area of research.

In most developing countries, tariffs and quotas play an especially important role, particularly in industrial policy. For example, the protection provided by tariff or quota policy can serve to prop up the home country's infant industry, and can also accelerate the home country's technological innovations.

The purpose of this research is to examine the upgrading of the technology levels of domestic firms when foreign exporting firms are subject to tariff or quota constraints; this is done in order to show which of these two policies, i.e., tariffs or quotas, is most effective in leading to the upgrading of the domestic firm's technology level.

Other investigations into topics similar to that presented in this paper are few in number. Spencer and Brander (1983) presents a theory of government intervention which provides an explanation for industrial strategy policies such as R&D and export subsidies in an imperfectly competitive international market. Reitzes (1991) discusses the influence of tariff and quota policy on the strategic research and development (R&D) competitive behavior of firms in trading nations. Reitzes' analysis focuses primarily on competition between firms in the field of R&D. He points out that even if quotas were set at a level higher than those found in free trade, R&D competition would still result in quota binding. Miyagiwa and Ohno (1995) alternatively examines which, either tariff or quota policy, could best encourage the early adoption of new technology in the competing sector of importing countries. Generally speaking, tariffs are more effective in achieving this. Such a move is undertaken for the purpose of narrowing the technology gap between competing firms in importing and exporting nations. Muniagurria and Singh (1997) examines the appropriate domestic R&D policy in an asymmetric duopoly with R&D rivalry and technological spillovers from the more advanced foreign firm. They have found that the optimal policy on domestic R&D and imitation depends crucially on the effect of foreign technology on domestic profits.

The present paper establishes a two-country, two-firm model to assess the effectiveness of the efforts of the importing country's firms, under a tariff or equivalent quota system, to make technological progress. We assume that if the technological levels of the foreign exporting firms were already known, then the importing country's firms could, through choosing their own technological standards, reduce the technology gap between themselves and firms in the exporting country. This paper examines how, under three different kinds of competitive condition, firms in the importing country decide upon what is for them the optimal level of technology. The competitive conditions studied in the paper are Cournot quantitative competition, Bertrand price competition, and more generalized competition with conjectural variation.

This paper is structured as follows: after the introduction, the second section presents the basic model of analysis used in this paper; sections three to five separately discuss the engagement of firms in Cournot competition, in Bertrand competition, and in competition with conjectural variation describing the effect of technological upgrading under these three differing competitive environments; the sixth and final section of this study serves as the conclusion.

II. The Basic Model

Let us suppose that the home country and the foreign country, as part of the international economic system, each have one firm operating in one particular industry. The foreign firm exports its goods to the home country, which are thereafter competing with a home firm in the home market. Competitive conditions between the firms of the two countries may take the form either of Cournot quantitative competition, more generalized conjectural variation competition, or Bertrand price competition.

The output of the home firm and that of the foreign firm is given by q and q^*, respectively. We also assume that the marginal costs of the firms in the home and the foreign countries are constant, and are given by c and c^*, respectively. Before production, the home firms first decide upon a certain level of technology for the production process. In this paper, the magnitude of the marginal cost c indicates the technology level, such that the smaller the value of c, the more superior the production technology selected by the home firm.[1] Suppose that when the firms in the home country select technological standards the cost is given by F.[2] The relationship of this cost to technological standards can be expressed as $c = c(F)$, with $c'(F) < 0$, $c''(F) < 0$, which indicates that when the technology

[1] A smaller marginal cost can be achieved through either cost-reducing R&D activity or technology-purchasing behavior.

[2] F can be taken as R&D outlay or the price of technology purchase.

costs are higher, the technology is better, and therefore the marginal production cost must be lower. However, the marginal effect decreases. For the sake of a more convenient analysis, we may inverse the function as follows: $F = F(c)$, $F' < 0$, $F'' < 0$, the meaning of which is as above-mentioned. We also assume, in order to simplify the analysis, that the technological standard of the foreign firm is pre-existing and fixed; therefore, only the home firm needs to select its technology level.[3]

According to the above assumptions, the model used in this paper is really a two-stage game: in the first stage, the firm in the home country, under tariff or equivalent quota policy, first chooses a technological level for production; in the second stage, the home firm proceeds with production according to the technological standard decided upon in the first stage. In order to obtain the model's subgame perfect equilibrium, we must search for a solution by going backwards. After obtaining the equilibrium of second-stage market competition, it can be substituted back into the first stage in order to seek out the optimal technology standard for the firm in the home country.

Under this model, we first analyze the home country's choice of an optimal technology standard when tariffs have been imposed against goods from the foreign country. Next, we investigate the home firm's technology level under the equivalent quota, i.e., when the quota volume is set at a level equal to that for the imports under the aforementioned tariffs. Finally, this paper discusses, between tariffs and quotas, which can best help boost levels of technological capability in the home country.

III. Cournot Quantitative Competition and Technological Upgrading

In this section, we examine the question of the optimal choice of a technology standard for the home firm when the following circumstances are prevailing in the home country, viz., the government has set in progress the adoption of a tariff or an equivalent quota policy, and the home firm is engaged in Cournot competition with the foreign firm. If the two firms produce and sell the same product in the home country's market, the inverse demand function may be expressed as $p = p(q + q^*)$.

Let us assume the home country's government imposes a specific tariff t on imports from the foreign firm. In the second stage, the two countries' firms, taking into account production costs and tariff rates, determine their optimal production output. The profit

[3] We may regard the home country as a developing country. Generally speaking, it is the typical state of affairs in developing countries that they foster the technological development of domestic firms while competing with developed countries, whose firms have already attained technological maturity.

functions of the home firm and the foreign firm are separately given by:

$$\pi(q,q^*) = (p-c)q - F(c) \quad (1a)$$
$$\pi^*(q,q^*) = (p-c^*-t)q^* \quad (1b)$$

The first-order condition of profit maximization is given by:

$$\pi_1 = p + qp' - c = 0 \text{ [4]} \quad (2a)$$
$$\pi^*_2 = p + q^* p' - c^* - t = 0 \quad (2b)$$

Assume then, that the second-order condition of profit maximization $\pi_{11} < 0$, $\pi^*_{22} < 0$ and the stability condition $D = \pi_{11}\pi^*_{22} - \pi_{12}\pi^*_{21} > 0$ are both satisfied.

Through the above first-order condition, we can obtain the two firms' output as a function of the technology standards and tariff rates of the home country, i.e., $\tilde{q} = \tilde{q}(c,t)$ and $\tilde{q}^* = \tilde{q}^*(c,t)$, and the corresponding price is represented by $\tilde{p}$. From the first-order condition, we may derive the effect that a change in the technology level of the home country has on the optimal production output of the two firms, thus:

$$\tilde{q}_c = \frac{\partial \tilde{q}}{\partial c} = \frac{\pi^*_{22}}{D} < 0 \,,\; \tilde{q}^*_c = \frac{\partial \tilde{q}^*}{\partial c} = -\frac{\pi^*_{21}}{D} > 0 \text{ [5]} \quad (3)$$

Equation (3) shows that the higher the standards of production technology in the domestic firm (the lower the marginal costs c), the greater its production output, and the lower the output of the foreign firm.

Now let us turn to the first stage problem. In the first stage, the home firm chooses an optimal level of technology in order to maximize profit, taking into account $\tilde{q} = \tilde{q}(c,t)$ and $\tilde{q}^* = \tilde{q}^*(c,t)$, which are derived from the second stage calculation. The profit function of the home firm can be written as $\pi = \pi(\tilde{q}(c,t), \tilde{q}^*(c,t), c)$, and the optimal technology level of the home firm can be derived from the following first-order condition for profit

[4] In what follows, subscripts are denoted to represent differentials.

[5] We may assume the competitive conditions between two firms are strategic substitutes, so then $\pi_{12} < 0, \pi^*_{21} < 0$. At this juncture, the reaction functions of the two firms are negatively sloped. For a detailed discussion of this, see Bulow et al. (1985).

maximization :

$$\frac{d\pi}{dc} = \pi_1 \tilde{q}_c + \pi_2 \tilde{q}_c^* + \pi_c = 0$$

As $\pi_1 = 0$ from (2a), the above first-order condition can be simplified as

$$\frac{d\pi}{dc} = -(\tilde{p} - c)\tilde{q}_c^* + (-\tilde{q} - F') = 0 \tag{4}$$

Assuming the second-order condition $\partial^2 \pi / \partial c^2 < 0$ is satisfied, the home firm's optimal technological standard can be determined by the above first-order condition. The second term in equation (4) is the "own effect" of technology choice: the marginal cost of upgrading technological standards is $-F'$, and the marginal benefit is $\tilde{q}$ (the savings in production costs due to the better technology). The first term in equation (4) is the "strategic effect": because $\tilde{q}_c^* > 0$, the term is therefore negative. Owing to technological improvement, the home firm can profit from the competition of the second stage; therefore, the strategic effect encourages the home firm to upgrade technology.

Now we shall analyze the selection of an optimal technological level by the home firm when, instead of a tariff, an equivalent quota is adopted by the home government. If we use $\overline{q^*}$ to stand for imports under the equivalent quota, then, by definition, $\overline{q^*} = \tilde{q}^*$.

Under the quota regime, the foreign firm's production is subject to the quota constraint. Hence, the price of the domestic market is solely determined by the home output, given foreign imports. The profit of the home firm can be expressed in the following function:

$$\pi(q, \overline{q^*}) = \left[p(q + \overline{q^*}) - c \right] q - F(c) \tag{5}$$

The first-order condition of the home firm's selection of optimal output in order to maximize profit is given by

$$\pi_1 = p + qp' - c = 0 \tag{6}$$

which implies that the optimal output of the home firm, $\hat{q}$, is itself a function of technology standards c and quota level $\overline{q^*}$, thus: $\hat{q} = \hat{q}(c, \overline{q^*})$.

In the first stage, the home firm selects its optimal level of technology, making use of the relation $\hat{q} = \hat{q}(c, \overline{q^*})$. Hence, we can specify the home firm's profit function as $\pi = \pi(\hat{q}(c, \overline{q^*}), \overline{q^*}, c)$. The first-order condition of profit maximization for the optimal technology is given by

$$\frac{d\pi}{dc} = \pi_1 \hat{q}_c + \pi_c = \pi_1 \hat{q}_c + (-\hat{q} - F') = 0$$

Substituting (6) $\pi_1 = 0$ into the above equation, the aforementioned first-order condition reduces to

$$\frac{d\pi}{dc} = -\hat{q} - F' = 0 \tag{7}$$

Let us assume that the second-order condition of profit maximization, $\partial^2 \pi / \partial c^2 < 0$, holds good. The optimal standard for technology, $\hat{c}$, can be determined by solving (7).

Through equations (4) and (7), we can compare the home firm's choice of optimal technological standards under the tariff and the equivalent quota policies. Comparing equations (4) and (7), we obtain the following proposition.

[Proposition 1] When the domestic and the foreign firms engage in Cournot quantitative competition, the home firm would employ a higher technology standard under the tariff policy than under the equivalent quota policy.

[Proof] Under Cournot competition, the home firm's output under the tariff and the equivalent quota policy is identical (i.e., $\tilde{q} = \hat{q}$). Substituting equation (7) and $\tilde{q} = \hat{q}$ into equation (4), we get

$$\left.\frac{d\pi}{dc}\right|_{\hat{q}, \hat{c}} = -(p - \hat{c})\hat{q}_c^* < 0 \tag{8}$$

which indicates that $\tilde{c} < \hat{c}$.

Under quota policy, the output of the foreign firm is assumed to be bound by the quota restriction; then the domestic firm can act as a Stackelberg leader, setting its output by taking into account the quota constraint of the foreign firm.[6] Because of this, the strategic effect does not appear (see equation (7)). The absence of the strategic effect leaves the home firm with less incentive to upgrade its technology. Consequently, the domestic firm has a greater incentive to upgrade technology under the tariff policy.

IV. Bertrand Price Competition and Technological Upgrading

In the preceding section, we analyzed the optimal technology choice of the home firm when the two firms engage in Cournot competition. In this section, we analyze the optimal technology choice of the home firm when the two firms engage in Bertrand price competition.

Let us suppose that the products of the two firms are substitutes, engaging in Bertrand price competition in the market of the home country. We assume the demands faced by the home firm and the foreign firm are given respectively by $q(p,p^*)$ and $q^*(p,p^*)$, where p and p^* are the prices of the products manufactured by the domestic and the foreign firm, respectively. For the sake of simplification, we also assume the aforementioned demand functions to be linear and symmetrical; this demand function therefore possesses the following properties: $q_1 = \frac{\partial q}{\partial p} = q_2^* = \frac{\partial q^*}{\partial p^*} < 0$, $q_2 = \frac{\partial q}{\partial p^*} = q_1^* = \frac{\partial q^*}{\partial p} > 0$, indicating that an increase in the price of each product decreases its own output, but increases the output of the other product. We can also define the product substitution rate as $s = -\frac{q_2}{q_1} = -\frac{q_1^*}{q_2^*}$, where the value of s lies between 0 and 1; the larger the value of s , the higher the degree of substitution between the two products.

Assuming that a specific tariff t is levied by the government of the home country on the foreign product, the profit functions of the domestic and the foreign firm are, respectively:

$$\Pi(p,p^*) = (p-c)q(p,p^*) - F(c)$$
$$\Pi^*(p,p^*) = (p^* - c^* - t)q^*(p,p^*)$$

The first-order conditions for this maximization problem are:

[6] This does not mean that tariffs or quotas change the timing of moves by firms. It is only meant in the sense that the quota constraint is known. A similar concept can be found in Itoh and Ono (1984).

$$\Pi_1 = (p - c)q_1 + q = 0 \tag{9a}$$

$$\Pi_2^* = (p^* - c^* - t)q_2^* + q^* = 0 \tag{9b}$$

The second-order conditions for profit maximization $\Pi_{11} = 2q_1 < 0$, $\Pi_{22}^* = 2q_2^* < 0$ and the stability condition $\Delta = \Pi_{11}\Pi_{22}^* - \Pi_{12}\Pi_{21}^* = q_1 q_2^* (4 - s^2) > 0$ are both satisfied.

Through the above first-order conditions, we can obtain the optimal prices of the two products as functions of the technological levels and the tariff rate of the home country; the optimal prices of the products in the home and the foreign firms in the two countries under tariff policy are thus given by $\tilde{p} = \tilde{p}(c,t)$, $\tilde{p}^* = \tilde{p}^*(c,t)$. Totally differentiating the first-order conditions with respect to c, $\tilde{p}$ and $\tilde{p}^*$ yields the following comparative static properties:

$$\tilde{p}_c = \frac{\partial \tilde{p}}{\partial c} = \frac{q_1 \Pi_{22}^*}{\Delta} > 0, \ \tilde{p}_c^* = \frac{\partial \tilde{p}^*}{\partial c} = \frac{-q_1 \Pi_{21}^*}{\Delta} > 0 \tag{10}$$ [7]

In the first stage, the home firm chooses the optimal level of technology by maximizing its profit function $\Pi = \Pi(\tilde{p}(c,t), \tilde{p}^*(c,t), c)$. The first-order condition of profit maximization is:

$$\frac{d\Pi}{dc} = \Pi_1 \tilde{p}_c + \Pi_2 \tilde{p}_c^* + \Pi_c = 0$$

We may assume that the second-order condition of profit maximization, $\partial^2 \Pi / \partial c^2 < 0$, is satisfied. Because $\Pi_1 = 0$ by (9a), the aforementioned first-order condition can be put in a modified form thus:

$$\frac{d\Pi}{dc} = (\tilde{p} - c)\tilde{q}_2 \tilde{p}_c^* + (-\tilde{q} - F') = 0 \tag{11}$$

The second term in equation (11) is the own effect of technology choice; the first term is the strategic effect. Because $\tilde{q}_2 > 0$, $\tilde{p}_c^* > 0$, this term is therefore positive, indicating that the strategic effect *reduces* the desire of the home firm to promote technology. This is

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[7] It is assumed that $\Pi_{21}^* > 0$, $\Pi_{12} > 0$. This is also the condition for positively sloped reaction functions, a common assumption in Bertrand competition.

because under price competition, the selection of relatively superior technology by the home firm lowers the optimal price of the foreign firm, which is detrimental to the home firm. Hence, in contrast to the positive strategic effect under Cournot competition, the strategic effect under price competition will dampen the desire of the home firm to technologically upgrade.

Next, if the home government, instead, erects equivalent quota measures against the foreign firm, then the quota level $\overline{q^*}$ is defined as:

$$\overline{q^*} = \tilde{q}^*(p, p^*) \tag{12}$$

We can rewrite this condition as $p^* = h(p)$ in order to indicate the relationship between quota restrictions, p and p^*. The slope of the h function is therefore:

$$h'(p) = \frac{dh}{dp} = -\frac{q_1^*}{q_2^*} = s \tag{13}$$

In the second stage, when quota restrictions against the foreign firm have been imposed, the home firm selects an optimal price to maximize its profit. Owing to the fact that the foreign firm's production output faces restrictions, when the home firm decides upon an optimal price, its situation is analogous to a monopolist facing a residual demand after subtracting a quota from the market demand. Therefore, the profit function of the home firm can be given by:

$$\hat{\Pi}(p, p^*) = (p - c)q^*(p, h(p)) - F(c) \tag{14}$$

The first-order condition of the home country's profit maximization is

$$\hat{\Pi}_1 = (p - c)(q_1 + q_2 h') + q = 0 \tag{15}$$

By substituting $h' = s$, $-q_2/q_1 = s$ into the above equation, we can express the above first-order condition in the following modified form:

$$\hat{\Pi}_1 = (p - c)q_1(1 - s^2) + q = 0 \tag{16}$$

Through the above first-order condition, we can obtain the optimal price of the home firm as a function of technology standards and quotas themselves, thus $\hat{p} = \hat{p}(c, \overline{q^*})$; similarly, the optimal price of the foreign firm is $\hat{p}^* = h(\hat{p}(c, \overline{q^*}))$; and the corresponding production output of the home firm is, then, $\hat{q}(\hat{p}, \hat{p}^*)$.

In order to compare the differences and similarities of the equilibrium prices under tariff and equivalent quota policies, we substitute equation (16) into equation (9a) to produce

$$\Pi_1\big|_{\hat{\Pi}_1=0} = s^2(\hat{p} - c)q_1 < 0 \qquad (17)$$

Accordingly, given the same technological standards, the home firm's equilibrium price under the tariff policy is lower than that under the equivalent quota policy. Moreover, from equation (12) of the quota constraint, the total effect on the domestic firm's output of the change in its own price is derivable as follows:

$$\frac{dq}{dp} = q_1 + q_2\frac{dp^*}{dp} = q_1(1 - s^2) < 0 \qquad (18)$$

which implies that as the home price goes up, the home firm's equilibrium output should go down. Because the price of the home firm is higher under the equivalent quota policy, it is conceivable, through equation (18), that the production output of the home firm is larger under the tariff policy than under the equivalent quota policy (i.e., $\tilde{q} > \hat{q}$).[8]

In the first stage, the home firm selects an optimal technology standard for the purpose of profit maximization. The profit function of the home firm may be written as $\Pi = \Pi(\hat{p}(c, \overline{q^*}), h(\hat{p}(c, \overline{q^*})), c)$. The first-order condition of maximizing profit is

$$\frac{d\hat{\Pi}}{dc} = \left[(p - c)(q_1 + q_2 h') + q\right]p_c + (-\hat{q} - F') = 0$$

We assume the second-order condition of profit maximization, as expressed $\partial^2\hat{\Pi}/\partial c^2 < 0$, is satisfied. Substituting (15) of the optimal price condition of the home firm into the above first-order conditions yields:

[8] For similar results, see Harris (1985) or Mai and Hwang (1988).

$$\frac{d\Pi}{dc} = -\hat{q} - F' = 0 \tag{19}$$

Like the former case of Cournot competition, under the quota constraint, the foreign firm becomes a follower while the home firm acts as a Stackelberg leader. Hence, the strategic effect does not appear in the quota regime.

From the comparison of equations (11) and (19), we can infer that under the tariff policy, the strategic effect leads to an inferior technology adopted by the home firm. But through equation (16), it is conceivable that under the tariff policy the production output of the home firm is higher compared to that under the equivalent quota and that this output effect provides an incentive for the home firm to technologically upgrade. Therefore, the question of which type of policy can best facilitate technological improvements in the home firm depends upon the respective magnitudes of the two effects.

Based on the above discussion, we can put forward the following proposition.

[Proposition 2] When the two countries' firms engage in Bertrand price competition, the superiority of the home firm's technology standard under the tariff and the equivalent quota policies is ambiguous as it depends on the output effect and the strategic effect. But, if the demand functions are linear and symmetrical, then the technology standards of the home firm are necessarily higher under the tariff policy than under the equivalent quotas.

[Proof] Under the quota regime, the production output of the home firm satisfies equation (16). Under the linear demand assumption, equation (18) can be modified to $d\hat{q} = q_1(1 - s^2)dp$ or $\tilde{q} - \hat{q} = q_1(1 - s^2)(\tilde{p} - \hat{p})$. Through the first-order condition of equations (9a) and (16), it may be inferred that $\tilde{p} = -\frac{\tilde{q}}{q_1} + c$, $\hat{p} = -\frac{\hat{q}}{q_1 + sq_2} + c$. With $\tilde{p} - \hat{p} = \frac{1}{q_1}\left[\frac{\hat{q} - (1 - s^2)\tilde{q}}{1 - s^2}\right]$ substituted into this equation, we get $\tilde{q} - \hat{q} = \hat{q} - (1 - s^2)\tilde{q}$, and hence $\hat{q} = (1 - \frac{s^2}{2})\tilde{q}$. Consequently, equations (11) and (17) can be rewritten:

$$\frac{d\Pi}{dc} = \frac{s^2}{4 - s^2}\tilde{q} + (-\tilde{q} - F') = 0 \tag{20}$$

$$\frac{d\hat{\Pi}}{dc} = -\tilde{q}(1 - \frac{s^2}{2}) - F' = 0 \tag{21}$$

Comparing equations (20) and (21) produces

$$\left.\frac{d\Pi}{dc}\right|_{\frac{d\tilde{\Pi}}{dc}=0} = (\tilde{p}-\bar{c})\tilde{q}_2\tilde{p}_c^* + (\hat{q}-\tilde{q}) = \frac{s^2}{4-s^2}\tilde{q} - \frac{s^2}{2}\tilde{q}$$

$$= -\tilde{q}\left(\frac{1}{2}-\frac{1}{4-s^2}\right)s^2 < 0 \qquad (22)$$

which indicates $\tilde{c} < \hat{c}$.

This proposition tells us that under tariff policy, although the strategic effect of market competition lowers the incentive of the home firm to enhance technology, yet the positive output effect dominates the negative strategic effect, leading to superior technology in the home firm.

Though the conclusions of Proposition 2 and Proposition 1 are similar, the rationale behind the similarity differ significantly. With Cournot competition, because the production output of the home firm is the same under both tariff and quota policies, the output effect consequently does not become a factor in the technology choice of the home firm. Under Cournot competition, the competitive condition of the two firms are strategic substitutes which yield a positive strategic effect. It is the positive strategic effect which gives the home country a heightened incentive to upgrade technology. However, under Bertrand competition, the competitive condition is a strategic complement which yields a negative effect; this negative strategic effect under tariff policy has the contrary effect of rendering the home firm less inclined to adopt better technology out of a desire to avoid excessively intense competition in the market. Therefore, as far as the strategic effect of technology choice under tariff policy is concerned, under Cournot competition the strategic effect is positive, which in turn has a positive effect on promoting technology in the home firm; but under Bertrand competition it is negative, and thus negatively influences technological upgrading. But because the production output of the home firm is higher under the tariff policy than under the equivalent quota, and become the output effect overtakes the strategic effect, the home firm tends to adopt better technology under the tariff policy under Bertrand competition.

V. Competition with Conjectural Variation and Technological Upgrading

In order to simplify our analysis we assumed, in the previous two sections, that the two firms play in either the Cournot or the Bertrand fashion, which in terms of conjectural variation, the value of the conjectural variation is zero. In this section, we shall modify this assumption and adopt a more generalized conjectural variation approach, investigating again the influence which tariff and quota policy have on the effectiveness of firms' selection of technology.

Under tariff policy and during the second stage, the two firms, taking as given the production costs and tariff rates, select an optimal production output in order to maximize profit. The profit function here is still the same as in equation (1). The first-order condition of the two firms' choice of optimal output for profit maximization becomes:

$$\pi_1 = p + q(1+\lambda)p' - c = 0 \tag{23a}$$
$$\pi_2^* = p + q^*(1+\lambda^*)p' - c^* - t = 0 \tag{23b}$$

where $\lambda = dq^*/dq$, $\lambda^* = dq/dq^*$, representing the quantity of the conjectural variation of the domestic and foreign firm, respectively, on the production output of the rival. For simplicity, we assume $\lambda = \lambda^*$. The value of conjectural variation λ can actually be taken as a market structural parameter: $\lambda = 0$ represents Cournot competition; when $\lambda > 0$, market equilibrium output is less compared to that under Cournot competition, and is thus a more collusive market condition; when $\lambda < 0$, the market equilibrium output exceeds that under Cournot competition, implying a more competitive market condition. When $\lambda = 1$, the market output is the same as the collusive output, and when $\lambda = -1$, the market output is the same as the competitive output. Hence, the value of λ lies somewhere between -1 and 1.

We shall assume that the second-order conditions for profit maximization $\pi_{11} < 0$, $\pi_{22}^* < 0$ and the stability condition $D = \pi_{11}\pi_{22}^* - \pi_{12}\pi_{21}^* > 0$ both hold true.

The two firms' optimal production output under tariff policy can be obtained through the above first-order condition which yields $\tilde{q} = \tilde{q}(c, t, \lambda)$ and $\tilde{q}^* = \tilde{q}^*(c, t, \lambda)$, and the corresponding price is $\tilde{p}$. Accordingly, the equilibrium output and price are susceptible to not only the technological standard and the tariff, but also the conjectural variation.

The impact of the change in the home country's technology standards on the firms' optimal output in both countries is expressed as:

$$\tilde{q}_c = \frac{\partial \tilde{q}}{\partial c} = \frac{\pi_{22}^*}{D} < 0,\ \tilde{q}_c^* = \frac{\partial \tilde{q}^*}{\partial c} = -\frac{\pi_{21}^*}{D} > 0 \tag{24}$$

In the first stage, the firm of the home country selects an optimal level of technology to maximize profit. In such a case, the profit function can be given by $\pi = \pi(\tilde{q}(c,t,\lambda),\tilde{q}^*(c,t,\lambda),c)$. The first order condition of profit maximization is then :

$$\frac{d\pi}{dc} = \pi_1 \tilde{q}_c + \pi_2 \tilde{q}_c^* + \pi_c = 0$$

We may assume that the second-order condition for profit maximization, $\partial^2\pi / \partial c^2 < 0$, is satisfied. By equation (23a), the above first-order condition can be rewritten as follows:

$$\frac{d\pi}{dc} = \frac{(\tilde{p} - c)\tilde{q}_c^*}{1+\lambda} + (-\tilde{q} - F') = 0 \qquad (25)$$

The home firm's optimal technological level can be derived from equation (25). The analysis here runs along similar lines to that in the previous section. The second term in equation (25) is the own effect of technology selection; the first term is the strategic effect of market competition, and since $\tilde{q}_c^* > 0$, and $\lambda > -1$, this term is still negative, so the strategic effect will accordingly encourage the domestic firm to adopt better technology.

Next, we shall investigate the choice of optimal technology standards of the home firm when the equivalent quota is in place. As before, the equivalent quota is defined as $\overline{q^*} = \tilde{q}^*$.

Under the quota regime, the profit function of the home firm is still of equation (5). The optimal output of the home firm can be derived from following the first-order condition:

$$\hat{\pi}_1 = p + qp' - c = 0 \qquad (26)$$

This first-order condition is the same as equation (6). This is because when production in the foreign firm is restricted by quotas, the conjectural variation of the home firm on the foreign output is always zero. As a result, conjectural variation does not appear in equation (26).

In order to compare the production output of the home firm under the tariff and the equivalent quota policies, we substitute equation (26) into equation (23a) to obtain:

$$\pi_1\Big|_{\hat{\pi}_1=0} = \lambda\hat{q}p' \quad (27)$$

Accordingly, given the same marginal cost c, the ranking of the production output of the home firm under either the tariff or the equivalent quota policy, is dependent on conjectural variation λ: when $\lambda > (<)0$, equation (27) is negative (positive), indicating that the production output of the home firm is smaller (larger) under the tariff policy than it is under the equivalent quotas. This is because a positive λ implies that the two firms play more collusive strategies under the tariff policy, and it therefore follows that the output of the domestic firm is smaller as compared to that under the equivalent quotas (under the quota policy, the domestic firm's conjectural variation is zero); if λ is negative, then this indicates that the behavior of the domestic firm under the tariff policy is more competitive, and it then follows that its output is higher compared to that under the equivalent quotas. This is the output effect brought about by conjectural variation.[9]

In the first stage, the home firm selects an optimal level of technology to maximize profit. In this stage, the profit of the home firm is represented by $\hat{\pi} = \hat{\pi}(\hat{q}(c,\overline{q^*}),\overline{q^*},c)$. The first-order condition for profit maximization is

$$\frac{d\hat{\pi}}{dc} = -\hat{q} - F' = 0 \quad (28)$$

We shall assume the second-order condition for profit maximization, $\partial^2\hat{\pi}/\partial c^2 < 0$, is satisfied. Equation (28) can be used to derive the optimal technology standard $\hat{c}$. Since equations (26) and (6) are identical, the implication is that the introduction of conjectural variation into the model yields no change in the selection of the home firm's technology level .

Through equations (25) and (28), we can compare the choice of optimal technology standards by the home firm under the tariff and the equivalent quota. Comparing equation (25) with equation (28), we obtain the following proposition.

[Proposition 3]

(1) If the conjectural variation $\lambda \le 0$, then the technology standard of the home firm is higher under the tariff policy than under the equivalent quota policy.

[9] See Hwang and Mai's (1988) analysis.

(2) If $\lambda > 0$, then it is indeterminant, between tariffs and quotas, which can best spur the promotion of the technological standards of the home firm. Only when the value of λ is large can the home firm, under the equivalent quota policy, attain better technology.

[Proof] Comparing equations (25) and (28) gives us

$$\left.\frac{d\pi}{dc}\right|_{\frac{d\pi}{dc}=0} = -\frac{(\tilde{p}-\hat{c})\tilde{q}_c^*}{1+\lambda} + (\hat{q}-\tilde{q}) \tag{29}$$

In the above equation, the first term, which represents the strategic effect, is negative. The positively or negativity of the second term is determined by conjectural variation. By equation (27), we may infer that when λ is positive (negative), $\hat{q} > (<)\tilde{q}$, so it follows that the second term is positive (negative). In summarizing the aforementioned two effects, we may also infer, when $\lambda \leq 0$, that equation (29) is negative, and thus $\tilde{c} < \hat{c}$; when $\lambda > 0$, whether equation (29) is positive or negative is uncertain, and subsequently the ranking of $\tilde{c}$ and $\hat{c}$ is ambiguous.

Although the strategic effect gives the home firm, under tariff policy, more of an incentive to upgrade technology, the output effect created by conjectural variation exerts an uncertain influence on the incentive to technologically upgrade. When conjectural variation $\lambda < 0$, the output of the home firm, under tariff policy, is greater, and because of this and purely as far as the output effect is concerned, tariff policy furnishes the home firm with more of an incentive to enhance technology. As the impacts of both the strategic effect and the output effect run parallel, we can consequently be sure that tariff policy provides the home firm with a greater motivation to promote technology. On the other hand, when conjectural variation λ is greater than 0, the production output of the home firm under tariff policy is relatively small, implying, as far as the output effect is concerned, that tariff policy serves as a disincentive to enhance technology. At such a juncture, the respective impact of the strategic effect and the output effect are going in opposite directions, with the result that we cannot know for sure whether or not tariff policy leads the home firm to adopt better technology.

The current model can easily be extended to analyze the situation with price conjectural variation. Mai and Hwang (1988) proves that when the price conjectural variation of two firms $dp^*/dp = \gamma$ is greater than the product substitution rate s as defined in this section, then the production output $\tilde{q}$ of the home firm under the tariff policy is less than the production output $\hat{q}$ under the equivalent quotas. It follows, then, that both the strategic effect and the output effect under tariff policy serve as a disincentive for technology upgrading for the home firm, and hence the equivalent quota policy can prompt the home firm to select superior technology. Based on the above discussion, we can put forward the following proposition.

[Proposition 4] When the two firms engage in price competition, if the price conjectural variation is greater than the product substitution rate, then the technology standards of the home firm under the equivalent quota policy are higher.

VI. Conclusion

This paper sets up a two-country, two-firm model. Under the three differing competitive conditions of Cournot quantitative competition, Bertrand price competition and conjectural variation, we separately compare the impacts of tariff and quota policies on the home firm's selection of technology standards.

When the two firms engage in Cournot quantitative competition, tariffs are more effective in upgrading the technology of the home firm than equivalent quotas are. This is due to the fact that under tariff policy, the promotion of technology can boost the home firm's market share at the expense of the foreign firm; hence the home firm profits. This is the so-called strategic effect a term which is commonly employed in industrial organization and trade literature. However, under the equivalent quota policy, the production output of the foreign firm is fixed and is not affected by the choice of the home firm's technology level (i.e., the strategic effect is absent); consequently the home firm has less incentive to upgrade its technology.

If we go a step further to consider a more generalized conjectural variation model, the aforementioned results undergo a change. This is because although the strategic effect under tariff policy gives the home firm more of an incentive to upgrade technology, the effect of the output effect produced by conjectural variation on the upgrading incentive is uncertain. When the conjectural variation between the two firms is negative, the production output of the home firm under tariff policy is higher, and therefore, as far as the output effect is concerned, tariff policy provides the home firm with a heightened incentive to undertake technological upgrading. In this circumstance, both the strategic effect and the output effect work in the same direction; hence, we can know for certain that tariff policy supplies the home firm with upgrading incentive. However, when the conjectural variation is positive, the production output of the home firm under tariff policy is lower, and as far as the output effect is concerned, the home firm has less incentive to promote its technology. In this case, the strategic effect and the output effect work in opposite directions, such that it cannot be ascertained whether or not tariff policy is relatively effective in expediting technology upgrading in the home firm.

When the firms in the two countries engage in Bertrand price competition under tariff policy, the strategic effect, which is absent under quota policy, is negative, dampening the desire of the home firm to enhance technology; but the output effect is positive and higher under tariffs than under equivalent quotas. The question of which type of policy can best facilitate the choice of superior technological standards by the home firm therefore depends upon the respective magnitudes of the two effects. Given the assumption of linear and symmetrical market demands, we are able to prove that the output effect outstrips the strategic effect, and that consequently tariffs are more effective than equivalent quotas in expediting the upgrading of technological standards in the home firm.

Moreover, if the firms in the two countries engage in price competition with conjectural variation, when the price conjectural variation is positive and sufficiently large, then the technology standard of the home firm is higher under equivalent quota policy. This is because in such a case the strategic effect and the output effect, under tariff policy, both act as disincentives for technological upgrading in the home firm.

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