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# On the Equivalence of Tariffs and Quotas with Endogenous Technology Choice

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Due to the implementation of policies by the WTO and as a result of the GATT, tariff barriers become less important instruments for protecting domestic industry. Some non-tariff barriers have emerged as substitutes to protect domestic industries. In this paper, we endogenize technology choice, allowing domestic firms to select different levels of technology with respect to tariff or quota protection. We then find that the equivalence of tariffs and quotas do not exist. We are also able to pinpoint which type of trade protection is most effective in bringing about the technological upgrading of domestic firms.

## I. Introduction

Theoretically, it has been proved already that free trade promotes the efficiency and the social welfare of a country. However, such a practice is still not adopted or executed in most countries. Though tariffs have up to the present descended markedly due to the continuous implementation of the GATT established in 1948 and as a result of its successor, the WTO, founded in 1995, there is still no way to make all the countries to remove entirely their tariff barriers. Meanwhile, abundant of researches have shown that non-tariff barriers (NTBs) are on an increasing trend (see also Reitzes and Grawe (1994), Palivos and Yip (1995)), in which quota policies, esp. the volume quotas are relatively a commonplace. However, in recent years, market share, which is also referred to as ratio quotas, is found to have been used as a trade-protecting tool in some cases. For example, in 1983 the United Steelworkers of America and the Bethlehem Steel Corporation ever brought forward bilateral negotiations with some major steel import countries to restrict the market share of the carbon and alloy steel imported at 18.5%. Later, such a mode was also adopted in the semiconductor agreement between the USA and Japan (Reitzes and Grawe (1994)). The function of tariffs is to raise the cost of imported goods, but NTBs influence the import volume. The price equivalence of tariffs and quotas has been attended by many experts and scholars in the past 30 years.

Bhagwati (1965) was the first to doubt the equivalence of tariffs and quotas. He believed that the price equivalence would be tenable only if perfect competition existed both at home and at markets abroad. While, Shibata (1968) believed that the price equivalence was still tenable only if perfect competition existed in domestic markets, no matter what

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form the foreign firm might be. In addition, Sweeney, Tower and Willett (1977) stated that if the market share quotas can make the domestic firm become a monopoly, then price equivalence is also held. Itoh and Ono (1982) utilized the Bertrand competition model to analyze the problem of price equivalence. Hwang and Mai (1988) deal with the cases of duopoly of homogeneous goods, which took a conjectural variation to analyze the price equivalence issue. They found that if firms competed with each other in the manner of Cournot, then the proposition of price equivalence could be established. Contrarily, if they compete more monopolistically than Cournot case, the price under tariffs will be higher than under quotas. Others authors who also take the conjectural variation method are Tasi and Chen (1994). They deemed that if the quota is binding, the equivalence is completely dependent on the types of the conjectural variation of domestic manufacturers. Otherwise, some scholars, such as Krishna (1989) and Dockner and Haug (1990), take various game theory to analyze this problem. Some authors such as Mullin (1993) and Ohta (1991) take monetary factors into consideration to discuss whether the price equivalence can be realized under a dual exchange market. Cunha and Santos (1996) stated that monopolist may use its preemption to buy the quota license to invalidate the quota, thus to affect the setting up of the price equivalence. Above-mentioned references pay most attention to the short run, i.e., suppose that the technical level of industries will not be improved by those trade-protecting policies.

For many countries, however, tariffs and quotas are expected to do the task of upgrading domestic industries. For instance, to protect the domestic infant industries, many developing countries will take the tariffs and quotas policies, the purpose of which is through these trade-protecting policies to upgrade the technical level of domestic firms and to strengthen their competitive advantages. So there have been many papers that have discussed the effects of tariffs and quotas on the increase of the technical level of domestic firms, for example, Reitzes (1991) analyzed the impact on R&D of tariffs and quotas. In addition, Miyagiwa and Ohno (1995) studied which of the two policies could upgrade a firm's technology level first. The focus of these papers lies on the comparison of the technical progressive effects caused by tariffs and quotas, respectively.

Based on the above discussions, we believe that to get a complete picture of the price equivalence problem, one must consider the motives behind the protecting-policies. The main purpose of this paper is to verify whether the price equivalence still holds or not when technological condition is determined endogenously. Furthermore, the paper compares the effects of various protection policies on technologies.

In this paper, we will discuss three popular quotas policies: volume quotas, market share quotas and value quotas, among which the volume quota is the most common. In the market share quotas, the quantitative limit on foreign sales is increasing with respect to domestic output. The value quota limits the total amount of import sales in domestic markets. Under the policies of market share quota and value quota, domestic firms can exert influences on the volume of imports through adjusting the production of their own.

The next section of the paper involves the setting of the basic model, which takes the Cournot model of duopoly in which two firms compete in terms of quantity produced. The third section discusses whether the price equivalence between tariffs and quotas still hold when the technology choice is endogenous. A comparison with previous references is also

given in this part. The fourth section compares the effects on technologies of the four protection policies, including the tariffs, the volume quotas, the market share quotas and the value quotas, respectively. In the last section some conclusions are drawn.

## II. The Model

Firstly, suppose that in an open economic system there are one domestic and one foreign firm competing in a Cournot duopoly game, whose production is $q^h$ and $q^f$ respectively, and with constant marginal cost $c^h$ and $c^f$ are the same as their corresponding average costs, separately. Before production and competition in the market, the domestic firm will choose a technology level, which can be represented with the magnitude of marginal cost. The smaller the marginal cost is, the better the technology choice is. Next, suppose that the technology choice of the foreign firm will not vary with that of the domestic firm. The cost of achieving the technology level chosen by the domestic firm is represented by *T*. For the convenience of analysis, this paper adopts the setting mode similar to that of Degraba (1990) and Choi (1995), that is we put $T = T(c^h)$ and $T' < 0$, $T'' > 0$, which state that the higher technology level does the firm try to obtain, the higher input cost it has to pay at an increasing rate.

Based on these assumptions, we use a two-stage Cournot duopoly model with one domestic firm and foreign firm. In the first-stage, the domestic firm will determine an optimal technology level against different protection policies. In the second-stage, the domestic firm will carry out a production with the technology level chosen in the first-stage and will compete in the domestic market with the foreign firm. We use the general backward induction to solve this model and obtain the sub-game perfect Nash equilibrium.

## III. The Price Equivalence between Tariff and Non-Tariffs Protection Policies

Since tariffs increase the costs for foreign suppliers, and quotas tend to restrict the quantity of foreign-supplied goods in domestic markets, both can cause an increase in price in domestic market. However, these two policies may induce different price changes in domestic market. To illustrate this, we examine the following analytical framework. First, the domestic firm chooses the optimal technology level to maximize its profits under tariffs, and therefore result in optimal output of both home and foreign firms. Next, we discussed the price equivalence of tariffs and quotas. To make this comparison effectively, we use the quantity obtained under tariff to be the limitation of quotas. This concept is considered in more detail in the following.

### 1. Tariff

Suppose that both the domestic and the foreign firms conduct a Cournot competition. The firms produce perfect substitutes, then the inverse demand function of domestic market is $p = p(q^h + q^f)$. If the government levies a tax $t$ on foreign-supplied goods by volume, then the profit functions of both the firms can be given respectively as:

$$\boldsymbol{p}^h(q^h, q^f) = (p - c^h)q^h - T(c^h)\,, \tag{1}$$

$$\boldsymbol{p}^f(q^h, q^f) = (p - c^f - t)q^f\,. \tag{2}$$

If taking the backward induction, then the first order conditions for the two firms are:

$$\boldsymbol{p}_1^h(q^h, q^f) = (p - c^h) + \tilde{q}^h p' = 0\,, \tag{3}$$

$$\boldsymbol{p}_1^f(q^h, q^f) = (p - c^f - t) + \tilde{q}^f p' = 0\,, \tag{4}$$

where the firms choose the optimal outputs to maximize their profits respectively. Suppose that both the second order conditions $\boldsymbol{p}_{11}^h < 0$ and $\boldsymbol{p}_{22}^f < 0$, and stability $D = \boldsymbol{p}_{11}^h \boldsymbol{p}_{22}^f - \boldsymbol{p}_{12}^h \boldsymbol{p}_{21}^f > 0$ are satisfied so that the global uniqueness of the equilibrium exists. Then Equations (3) and (4) can be used to obtain the equilibrium of solution of $\tilde{q}^h = \tilde{q}^h(c^h, t)$ and $\tilde{q}^f = \tilde{q}^f(c^h, t)$, both of which are the functions of the domestic technology level and the tariff. In addition, by totally differentiating the first order conditions, the effect on the outputs by varying from the technology level of both the countries can be obtained.[1] In which $\tilde{q}_c^h < 0$, which states that the domestic output will go up with the progress of the domestic firm's technologies; $\tilde{q}_c^f > 0$ represents that the import volume will reduce with the progress of the domestic firm's technologies. Meanwhile, the profit function can be rewritten as $\tilde{\boldsymbol{p}} = (\tilde{q}^h(c^h, t), \tilde{q}^f(c^h, t), c^h)$.

Prior to the first stage, the domestic firm will choose the optimal technology level to maximize its profit with the first order condition being:

$$\frac{d\tilde{\boldsymbol{p}}^h}{dc^h} = -(\tilde{p} - \tilde{c}^h)\tilde{q}_c^f + (-\tilde{q}^h - T') = 0\,. \tag{5}$$

Assuming that the second order conditions to maximize its profit is satisfied with $\frac{\partial^2 \tilde{\boldsymbol{p}}^h}{\partial (c^h)^2} < 0$, the optimal technology choice $\tilde{c}^h$ determined by the domestic firm can be obtained from Equation (5). Equation (5) consists of three terms: the marginal cost of upgrading technological level is $-T'$, and the marginal benefit is $\tilde{q}^h$ (the savings in production costs due to the better technology). The first term is the "strategic effect", because $\tilde{q}_c^f > 0$, 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.

By substituting $\tilde{c}^h$ into $\tilde{q}^h$ and $\tilde{q}^f$, and also substituting $\tilde{q}^h$ and $\tilde{q}^f$ into the inverse demand function, the domestic market price $\tilde{p}$ under tariffs can be obtained.

1. For details see Appendix I.

**2. Quotas**

Now we solve the optimal output and technology level of the domestic firm under quotas. Let the policy maker commit to volume quota, the ratio quota and the sales quota as $\overline{q}^f$, $r$ and $v$ respectively. In order to compare with the tariff case, it is supposed that the magnitudes of quota happen to be equal to those when tariff stay in equilibrium. Namely, under the volume quota, $\overline{q}^f = \tilde{q}^f$, under the ratio quota, $r = \tilde{q}^f / \tilde{q}^h$, and under the sales quota $v = p(\tilde{q}^h + \tilde{q}^f)\tilde{q}^f$. These relationships could be also represented as $q^f = H(q^h)$.

In the second stage, the domestic firm will first choose the optimal output to maximize its profit under the volume quotas policy, hence the profit function of the domestic firm can be given as:

$$\boldsymbol{p}^h(q^h, H(q^h)) = \left[p(q^h + H(q^h)) - c^h\right] q^h - T(c^h) . \tag{6}$$

The first order condition of the above function is:

$$\frac{d\hat{\boldsymbol{p}}}{dq^h} = (1 + H')\, \hat{p}' \hat{q}^h + p - c^h = 0 . \tag{7}$$

From Equation (7) we obtain the optimal quantity $\hat{q}^h(c^h, H')$ of the domestic firm under the quota policy, where $H' = \dfrac{dq^f}{dq^h}$. In the case of the volume quota where $q^f$ is a constant, $H' = 0$ while, under the ratio quota, we have $H' = r$ and under the value quota we have $H' = \dfrac{-p'q^f}{p'q^f + p}$.

Substituting $\hat{q}^h$ into Equation (6), then the profit function can be described as

$$\hat{\boldsymbol{p}}(c^h) = \left[p(\hat{q}^h + H(\hat{q}^h)) - c^h\right] \hat{q}^h - T(c^h) . \tag{8}$$

In the first stage, the domestic firm determines the optimal technology level to maximize its profit. By using Equation (7) the first order condition for the above function can obtained as

$$\frac{d\hat{\boldsymbol{p}}^h}{dc^h} = -\hat{q}^h - T' = 0 . \tag{9}$$

Supposing that the second order condition to maximize the profit holds, i.e., $\dfrac{\partial^2 \hat{\boldsymbol{p}}^h}{\partial (c^h)^2} < 0$, and according to the above first order condition, the optimal technology level of the domestic firm under quotas is $\hat{c}^h$.

### 3. The Price Equivalence between Tariffs and Quotas

From the previous two sections we have obtained the optimal output and technology level separately under the tariff and the quota policies. The next to be discussed is the price equivalence between tariffs and quotas.

Substituting the first order condition of the domestic firm under quota (i.e., Equation (9)) into the first order condition under the tariff (i.e., Equation (5)), we obtain

$$\left.\frac{d\tilde{p}^h}{dc^h}\right|_{\frac{d\hat{p}^h}{dc^h}=0} = -(\tilde{p}-\hat{c}^h)\tilde{q}_c^f + (-\tilde{q}^h + \hat{q}^h)\,, \tag{10}$$

where $\tilde{p}$ and $\tilde{q}_c^f$ are both constants in the case that $c^h = \hat{c}^h$. If the sign of Equation (10) is negative (positive), it states that $\tilde{c}^h$ is less (more) than $\hat{c}^h$, namely, the effect of technological improvement under the tariff is superior to that under quota. Hereinafter we discuss respectively the sign of Equation (10) and the price equivalence between tariffs and quotas according to the significance of each quota.

#### a. Volume Quota

According to the previous suppositions, the import volume under the volume quota should be equal to that under tariffs, vaz. $\bar{q}^f = \tilde{q}^f$, and the domestic output, $\bar{q}^h = \bar{q}^h(c^h, \bar{q}^f)$, should be identical with the output when tariffs are levied (namely $\tilde{q}^h = \bar{q}^h$),[2] hence Equation (10) can be rewritten as:

$$\left.\frac{dp^h}{dc^h}\right|_{\frac{d\hat{p}^h}{d\hat{c}^h}=0} = -(\tilde{p}-\bar{c}^h)\tilde{q}_c^f < 0\,. \tag{11}$$

2. It is not possible to use the first order conditions in Equations (3) and (7) to obtain directly the short equations for the optimal outputs $\tilde{q}^h$ and $\hat{q}^h$ of the domestic firm respectively under tariffs and quotas and to compare the magnitudes of both, however, from the supposition that the profit function is concave, by substituting $\tilde{q}^h$ and $\tilde{q}^f$ into the marginal profit function under the quota, and by use of the first order condition under the tariff, one can obtain

$$\left.\frac{d\hat{p}^h(q^h, H(q^h))}{dq^h}\right|_{\substack{q^h=\tilde{q}^h \\ q^f=\tilde{q}^f}} = H'\hat{p}'\hat{q}^h \le 0$$

From the above equation it can be found that when keeping constant at the same $c^h$, the magnitude of both are related to $H'$: (I) for the volume quota, since $H' = 0$, the outputs of the domestic firm respectively under tariffs and quotas are identical. (II) for the sales and the ratio quota, since $H' > 0$, then the optimal outputs of domestic firm under these two cases are less than the one under the tariff.

where $\bar{c}^h$ is the technology level of the domestic firm under the volume quota. Since the value of Equation (11) is less than zero, it can be understood that $\tilde{c}^h < \bar{c}^h$, which states that the technology level determined under the tariff is better than the one chosen under the volume quota. The reason is that under the volume quota the foreign firm has a fixed output and the domestic firm can not exert an influence on the import volume by means of choosing a better technology choice, $c^h$ is higher (i.e., losing the strategic effect mentioned in some references). As a result, the incentive for the domestic firm to improve its technologies is low.

On the other hand, substituting $\tilde{c}^h$ and $\bar{c}^h$ into Equation (3)[3] it can be shown that since $\tilde{c}^h < \bar{c}^h$ and $\tilde{q}^h_c < 0$ the output of the domestic firm under the tariff is higher than under the volume quota (i.e., $\tilde{q}^h(\tilde{c}^h, t) > \bar{q}^h(\bar{c}^h, t)$). Therefore, the total output ($\tilde{Q}$) in the domestic market under the tariff should be higher than the one ($\bar{Q}$) under the volume quota, that is

$$\tilde{Q} > \bar{Q}. \tag{12}$$

By Equation (12) it can be deduced that the domestic market price ($\tilde{p}$) under the tariff is less than the price ($\bar{p}$) under the quota limit. Thus, the price equivalence does not stand, as shown in Equation (13).

$$\tilde{p} < \bar{p}. \tag{13}$$

These relations can also be shown in Figure 1, in which point "A" is the equilibrium under a supposed tariff, the domestic and the foreign goods is respectively $\tilde{q}^h$ and $\tilde{q}^f$, the reaction curve of the domestic firm is $RF^h$. Since it has been supposed that the volume quota $\bar{q}^f$ is equal to the optimal output $\tilde{q}^f$ under the tariff, so the reaction curve of the foreign firm becomes the straight line $\bar{q}^f$ $\bar{q}^f$ in the Figure 1. Since $\tilde{c}^h < \bar{c}^h$, it can be seen from Equation (3) that the reaction curve of the domestic firm has a larger intercept under the tariff, i.e., the reaction curve of the domestic firm under the volume quota moves inward to $RF^{h'}$, in which case the balance point is "B". By comparing "A" with "B" the above result can be obtained.

**b. Ratio Quota**

Similarly, the output and the technology choice of the domestic firm under the ratio quota can be supposed respectively to be $\hat{q}^h$ and $\hat{c}^h$. Since Equation (10) is still less than zero, it states that the technology choice of the domestic firm under the tariff is better than under the ratio quota (namely $\tilde{c}^h < \hat{c}^h$). By the same deduction, it can be shown that

3. on the supposition that $\bar{q}^f = \tilde{q}^f(c^h, t)$, the connotations of Equations (3) and (7) are the same, therefore, the domestic technology choice under the volume quota can be substituted into Equation (3) to conduct a comparison.

$\hat{q}^h < \tilde{q}^h$. Let the foreign volume under the ratio quota be $\hat{q}^f$, to keep the ratio *r* a constant, there must be $\hat{q}^f < \tilde{q}^f$ (see Point C in Figure 1). If $\hat{Q}$ and $\hat{p}$ is respectively the total output and the price in the domestic market under the ratio quota, then the following result can be obtained:

$$\tilde{Q} > \hat{Q}, \text{ so } \tilde{p} < \hat{p}. \qquad (14)$$

The above equation states that under the ratio quota the market price will be higher than under the tariff, so the price equivalence of both can not be held.

**Figure 1 The Reaction Function and Output for Tariff and Quota**

**c. Sales Quota**

With regard to the case under the sales quota, it can also be obtained from the result in Equation (10) that the technology choice under the tariff is promoted higher than under the ratio ($\tilde{c}^h < \dot{c}^h$), and the output under the ratio quota is smaller than under the tariff ($\dot{q}^h < \tilde{q}^h$). In analysis of the price equivalence, when the output of the domestic firm under the sales quota is lower than under the tariff, for keeping the constant market sales of imports, there might be two possibilities. First, the domestic market price goes up and the import volume goes down. Second, the domestic market price goes down and the import volume goes up. Both the cases spoil the price equivalence. Although we can not evaluate both $\dot{q}^f$ and $\tilde{q}^f$ and further to compare domestic market prices under the sales quota and under the tariff, it is highly possible that the price equivalence of tariff and value quota is not held.

In contrast, Hwang and Mai (1988) assume that technology exogenously, accordingly, it can be found that the price equivalence between tariffs and quotas can hold (see Table 1).

In this paper, if we take technology exogenously, we could also obtain the price equivalence.[4] Otherwise, the domestic market price under the volume and the ratio quota is higher than under the tariff. In the case of the sales quota, it depends according to the market demand condition. The domestic market price under such case is either higher or lower than under the tariff, but not equal to. These results are also listed in Table 1.

**Table 1 The Comparisons between Tariff and Quotas**

| Policies | Domestic Output ($q^h$) | Foreign Output ($q^f$) | Total Output ($Q$) | Price Equivalence ($p$) | Marginal Cost ($c^h$) |
|---|---|---|---|---|---|
| Volume Quota | Reduce (same) | same (same) | reduce (same) | higher (same) | higher (same) |
| Ratio Quota | Reduce (same)* | reduce (same)* | reduce (same)* | higher (equal)* | higher (equal)* |
| Value Quota | Reduce (same)* | uncertainty (uncertainty) | uncertainty (uncertainty) | Non-equal (uncertainty) | higher (equal) |

Note: Values in parentheses are results under technological exogenously, also the results of Hwang and Mai (1988).

* Indicates the domestic firm's conjectural variation under quota is equal to tariffs case, then $\bar{q}^h = \tilde{q}^h$, the Cournot case leads to equivalence.

## IV. Comparison of Tariffs and Quotas in Technology Progress

The results in this paper can be used not only in analysis of the price equivalence between tariffs and quotas, but also in comparison of the technology progress effects under various quotas. For one thing, let us compare the technology progress effects under the volume quota and the market share quota. By using Equation (9), and substituting $-\bar{q}^h(\bar{c}^h, H') - T' = 0$, the first order condition under the ratio quota, into the first order

4. In such a case, as shown in footnote 2, for the volume quota, since $H' = 0$, the outputs of the domestic firm respectively under tariffs and quotas are identical, therefore the price equivalence is hold. For the value and the ratio quota, since $H' > 0$, then the optimal outputs of domestic firm under these two cases are less than the one under the tariff. However, if we allowed for other types of behavioral conjecturals in this model, the domestic firm's reaction function under tariffs becomes:

$$\pi_1^h(q^h, q^f) = (p - c^h) + p'(1 + \frac{dq^f}{dq^h})\tilde{q}^h = 0. \qquad (3')$$

We are now to compare the output by the domestic firm under quota and under the equivalent tariffs. To examine this, we can evaluate Equation (7) at $q^h = \tilde{q}^h$ and use Equation (3′) to obtain:

$$\left.\frac{d\hat{p}^h(q^h, H(q^h))}{dq^h}\right|_{q^h=\tilde{q}^h} = (H' - \frac{dq^f}{dq^h})\hat{p}'\hat{q}^h = 0 \quad \text{if} \quad H' = \frac{dq^f}{dq^h}.$$

Namely, if the domestic firm's conjectural variation under quota is equal to tariffs case, then $\bar{q}^h = \tilde{q}^h$, the Cournot case leads to equivalence.

condition under the ratio quota, it can be obtained[5] that

$$\left.\frac{d\bar{p}^h}{dc^h}\right|_{\frac{d\bar{p}^h}{d\bar{c}^h}=0} = -\bar{q}^h(\bar{c}^h, \bar{q}^f) + \bar{q}^h(\bar{c}^h, H') < 0 . \tag{15}$$

The above equation less than zero states that $\bar{c}^h < \hat{c}^h$, i.e., the technology progress effect under the volume quota is superior to under the ratio quota.

Similarly, substituting the first order condition under the sales quota into the first order condition under the volume quota, it can be got that

$$\left.\frac{d\hat{p}^h}{dc^h}\right|_{\frac{d\hat{p}^h}{d\hat{c}^h}=0} = -\hat{q}^h(\dot{c}^h, r) + \dot{q}^h(\dot{c}^h, \frac{dq^f}{dq^h}) . \tag{16}$$

The sign of Equation (16) will be maintained indefinitely if the ratio of the outputs of the two countries is equal to the ratio of changes (i.e., $\frac{q^f}{q^h} = \frac{dq^f}{dq^h}$), then Equation (16) is zero. This tells us that both the quotas exert same effect on the technology upgrade. However, when the ratio of the two output changes is more than the ratio of the two outputs, the sign of Equation (16) will be negative, which shows $\dot{c}^h > \hat{c}^h$. This result means that the technological upgrading effects under the ratio quota is better than under the sales quota.[6] Contrarily, the effect under the ratio quota is worse than under the sales quota.

According to the analysis above, it can be seen that the best technological upgrading effect happens under tariffs, and next under volume quota. While, the effects under the ratio and the sales quota depend on the output ratio and the output change ratio between the domestic and the foreign firms. The interpretation of above is that, under tariffs the quantity of foreign-supplied goods will not be limited, therefore, the domestic firm is confronted with a larger market competitive pressure. In addition, the existence of the strategic effect can induce the domestic firm to improve its technologies to restrain the import volume. With these two factors, technological upgrading effect under the tariff is the best.

In the case of the volume quota, the domestic firm has no way of limiting the import volume, that is, little incentive to enhance its technologies level. Finally, under the market share quota and the sales quota, as an effect of the domestic technological progress, the domestic output increase, and on the supposition that all the quota are binding, the foreign output will simultaneously increase at the same ratio or at the same change ratio. Thereby, under these two quotas the incentive for the domestic firm to upgrade its technological level the worst.

5. For details see Appendix II.

6. For details see Appendix II.

## V. Conclusion

Tariffs and quotas have been since beginning of the 20th century the most commonly-used trade protection tools, thus there have been many references in the research on the price equivalence problem. Since the motive behind trade protection is often to improve the technology standard of the domestic firm and enhance its competence, so it shall be more meaningful to discuss the price equivalence problem from the point of view that the choice of technology level is endogenous.

Through the above analysis it is found that if the technology level is endogenous, then the domestic market price under the tariff is lower than under the volume and the ratio quotas, but it may be either higher or lower than the price under the sales quota. In any case, the price equivalence is not guaranteed in general.

In addition, through investigation of the four protection policies it is found that for promotion of technologies the tariff policy is the most evident means, next is the volume quota. On the while the technological upgrading effects under the ratio and the sales quota depend on the output ratio and the output change ratio between the domestic and the foreign firms. The above results can be summarized as follows: 1) under tariffs, the domestic firm is confronted with a larger market competitive pressure, hence it has relatively the more the incentive to improve its technologies; 2) under the volume quota, the domestic firm cannot limit the import volume by determining a better technology level, thus the technological upgrading effect under this policy is worse than under the tariff; 3) under the ratio and the sales quotas, the output increase caused by the domestic technological progress allows the import volume to increase at the same ratio or at the same change ratio and thus the technological upgrading effects of the domestic firm are the worst.

Here is suggested some policy implications. If a government pays more attention to the welfare of domestic consumers, the tariff policy should be adopted since the domestic market price is lower than under the volume quota. If a government pays more attention to the domestic technological upgrading effect, then the first to be adopted is the tariff policy, and the next is the volume policy.

# Appendix I

By a totally differential of the first order condition, the influence of the domestic technology choice variation on the quantities of two countries can expressed as

$$\begin{bmatrix} 2\frac{\partial p}{\partial \tilde{q}^h} + \frac{\partial^2 \tilde{q}^h}{\partial (\tilde{q}^h)^2} & \frac{\partial p}{\partial \tilde{q}^f} + \frac{\partial^2 p}{\partial \tilde{q}^h \partial \tilde{q}^f}\tilde{q}^h \\ \frac{\partial p}{\partial \tilde{q}^h} + \frac{\partial^2 p}{\partial \tilde{q}^f \partial \tilde{q}^h} & 2\frac{\partial p}{\partial \tilde{q}^f} + \frac{\partial^2 p}{\partial \tilde{q}^f} \end{bmatrix} \begin{bmatrix} \frac{\partial \tilde{q}^h}{\partial c^h} \\ \frac{\partial \tilde{q}^f}{\partial c^h} \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{A1}$$

$$\tilde{q}_c^h = \frac{\partial \tilde{q}^h}{\partial c^h} = \frac{\boldsymbol{P}_{22}^f}{D} < 0 \quad \text{and} \quad \tilde{q}_c^f = \frac{\partial \tilde{q}^f}{\partial c^h} = -\frac{\boldsymbol{P}_{21}^f}{D} > 0 .$$

## Appendix II

In order to compare the quantities of domestic firms under the volume and the ratio quota, the supposition that a profit function should be concave can be used. Substituting $\bar{q}^h, \bar{q}^f$ into the marginal profit function under the ratio quota, and using the first order condition under the volume quota we get:

$$\left.\frac{d\hat{p}^h(q^h, H(q^h))}{dq^h}\right|_{\substack{q^h=\bar{q}^h \\ q^f=\bar{q}^f}} = H' \frac{\partial p}{\partial \bar{q}^h} \bar{q}^h < 0 . \qquad \text{(A2)}$$

Since the above equation is less than zero, it can be concluded that the optimal quantity under the volume quota is larger than that under the ratio quota.

Similarly, by substituting the FOC under the ratio quota into the FOC under the value quota, we get

$$\left.\frac{d\hat{p}^h(q^h, H(q^h))}{dq^h}\right|_{\substack{q^h=\hat{q}^h \\ q^f=\hat{q}^f}} = \left(\frac{d\hat{q}^f}{d\hat{q}^h} - \frac{\hat{q}^f}{\hat{q}^h}\right) \frac{\partial p}{\hat{q}^h} \hat{q}^h . \qquad \text{(A3)}$$

By this time if the domestic and foreign quantity change ratio is larger than the quantity ratio, Equation (A3) will be less than zero, which states that the domestic quantity under the ratio quota is higher than that under the sales quota. Using the same method, it can be obtained that the optimal quantity under the sales quota is less than that under the volume quota. The same process is not given in detail any more.

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