Minimum Quality Standard and International Rivalry in Quality and Price

Pei-Cheng Liao and Kar-yiu Wong
University of Washington

May 30, 2002
(First Draft. Comments Most Welcome.)

Abstract

This paper examines the policy interactions between two governments in an international duopoly model with vertical product differentiation, in which the foreign firm produces the low-quality good and exports to the home market. Whether the home government imposes a specific tariff or not, the foreign government has an incentive to set a minimum quality standard (MQS) on its exports, and the level of MQS decreases as the specific tariff increases. If the cost asymmetry between two firms is small enough, a foreign MQS can induce the home government to set the tariff below the prohibitive level, allowing more exports to the home country. However, if the foreign government is inactive, the home government will always set a high tariff close to the prohibitive tariff to allow a small trade from the foreign country. This paper shows that a MQS policy adopted by the foreign government not only helps the foreign firm behave as a Stackelberg leader to choose the quality level ahead of the home firm, but also serves as a strategic instrument to reduce the tariff imposed on its exports.

1 Introduction

The use of strategic trade policy to promote trade has been proven to be disruptive in world trade. One of the achievements of the GATT and the WTO is to prohibit the use of subsidies, and it regulates the actions countries can take to counter the effects of subsidies. It says a country can use the WTO's dispute settlement procedure to seek the withdrawal of the subsidy or the removal of its adverse effects. Or the country can launch its own investigation and ultimately charge extra duty (known as "countervailing duty") on subsidized imports that are found to be hurting domestic producers.

The Agreement on Subsidies and Countervailing Measures ("SCM Agreement") defines what constitute subsidies that governments are not allowed to impose. The definition contains three basic elements: (i) a financial contribution (ii) by a government or any public body within the territory of a member country (iii) which confers a benefit. The first part, a financial contribution, seems to be a crucial part in the measure.[1] Thus, there could be no subsidy unless there was a charge on the public account; for example, grants, loans, equity infusions, loan guarantees, fiscal incentives, the provision of goods or services, and the purchase of goods. It turns out that there are many other government policies that do not involve financial contributions but that can be used strategically to confer a benefit. This paper considers one such policy: minimum quality standard.

Minimum quality standards (MQS) are usually used in closed economies to improve the quality of goods produced in the market; for example: the requirement of air bags and ABS, fuel-economy standards and automobile emissions standards in the car industry. Usually the use of MQS is justified by the existence of moral hazard or the cost of inspection by the government, and appropriate use of MQS is welfare improving.[2]

There has also been work on analyzing the use of MQS for open economies. One of the earlier papers was Krishna (1987), who analyzes the effects and desirability of quotas, tariffs, and MQS when the foreign firm is a monopolist in the home market. In a model of international duopoly, Das and Donnen-

[1] A stronger definition of subsidy, which was suggested by some member countries, considers that forms of government intervention that did not involve an expense to the government nevertheless distorted competition and should thus be considered to be subsidies. This stronger definition was not adopted.

[2] See, for example, Crampes and Hollander (1995), Ecchia and Lambertini (1997), Ronnen (1991), and Crampes and Hollander (1995).

feld (1989) analyze the effects of quotas and MQS when both firms choose quality and quantity simultaneously to compete in the home market. They show that a MQS above the free trade level on the low-quality imports is welfare deteriorating to the home country. Boom (1995) considers the effects of different MQS levels set by two countries, with both firms competing in both countries. Compared to the identical MQS case, if one country sets a higher MQS than the other country, both firms are hurt while consumers in both countries benefit, but the welfare effect is ambiguous. Lutz (2000) analyzes and compares the two alternative standard-setting treatments of full harmonization and mutual recognition in a two-country, two-firm model. Under the condition that both firms must stay in the market, mutual recognition is always the optimal policy.

However, little work has been done to analyze MQS when used as a strategic trade policy. As the above papers show, MQS is often imposed on industries that are characterized by imperfect competition. When the quality levels of firms' outputs are determined endogenously, and when firms compete in quality (and possibly in price as well), the policy of MQS could have important effects on firms' profits and national welfare of the economies. This means that there could be situations in which MQS can be used strategically to improve a country's national welfare. It is thus the purpose of this paper to find out some of these situations, and to analyze the impacts of this policy.

Like other strategic policies, MQS is likely detrimental to its trading partner, and thus will likely draw retaliation. This paper will also analyze one retalitory policy: a tariff. If, however, the country that imposes MQS anticipates that its trading partner is going to retaliate, it may impose a higher MQS.

Since MQS is usually not seen as a trade promotional policy, it is allowed by at least the current version of SCM Agreement. In other words, it may be more difficult for an importing country that is facing a MQS to argue for retaliation at the WTO. However, this paper argues that some domestic policies such as MQS can be used strategically in an international context, and should not be ignored by the SCM Agreement.

To analyze the strategic nature of MQS in an international context, we consider a two-country, two-firm model, with demand in one of the countries only. We show that the exporting country (foreign) that has a firm producing the good of a low quality can use a MQS to improve the firm's profit and its welfare, at the expense of the firm in the importing country (home), even though such a policy will encourage both firms to improve the quality of their outputs. Even though the policy benefits the consumers in the home country, it could hurt the home country's welfare. This will induce home country to retaliate with a tariff. However, the outcome depends on the timing of the policies. Under the present WTO arrangement, it is possible that a country may make the first move and wait for the other country to react (complain to the WTO). In such a case, the first country will want to impose a MQS higher than than that without retaliation.

The remainder of the paper is organized as follows: Section 2 considers a closed economy in which a monopolist chooses the quality level of its output to serve a local market. Section 3 extends the model to two countries, with one firm in each of the countries. How the two firms compete in quality and prices is examined. An asymmetry between the countries is introduced, with the firms possessing different technologies of quality improvement and with market demand only in the country with an advanced firm. The use of minimum quality standard by the government of the country that has a firm with an inferior technology in quality improvement is investigated in Section 4. Section 5 shows how the advanced country can retaliate with a tariff. However, if the advanced country has to wait for the MQS before a tariff is imposed, the inferior country can take advantage of this sequence of policies and get a higher welfare. Section 6 provides some concluding remarks.

2 The Model

Consider a product with various quality levels. It can be produced by two firms, one in each of two countries. Label the countries home and foreign, and the firms home firm and foreign firm. Demand exists in the home country only, implying that any output of the foreign firm will be exported to the home country. In home, there is a continuum of consumers indexed by θ, uniformly distributed in the interval $[\underline{\theta}, \bar{\theta}]$. The parameter θ represents consumers' marginal willingness to pay for quality: Consumer θ has unit demand for the good and his utility function is:

$$U = \begin{cases} \theta s_i - p_i & \text{if buying one unit of the good with quality } s_i \text{ at price } p_i. \\ 0 & \text{otherwise.} \end{cases}$$

In this section, we focus on the home country, assuming no trade and thus no production by the foreign firm. So the home firm is a monopolist in the local market.

In the home economy, there is a single firm, which is able to produce the product of a quality s_0 with a unit cost α. We assume that $2\underline{\theta}-\bar{\theta} \geq \alpha/s_0 > 0$. As explained below, the condition implies that the entire market is always fully covered by the product of the home firm, i.e., every consumer in the home market will choose to purchase one unit of the good in equilibrium. This section considers a closed home economy.

2.1 Product with a Fixed Quality

Assume for the time being that the quality of the product is fixed at s_0. The market equilibrium depends on whether the market range is big enough. Two cases can be considered.

Case (A): $\underline{\theta} < (\bar{\theta} + \alpha/s_0)/2$

Suppose that the home firm chooses to serve $[\theta_0, \bar{\theta}]$ of the market and set the price of the output at $p_h = \theta_0 s_0$, where subindex "h" denotes variables of the home firm. Its problem is to choose the optimal value of θ_0 to maximize its profit, $\pi_h = (\theta_0 s_0 - \alpha)(\bar{\theta} - \theta_0)$, where $\bar{\theta} - \theta_0$ is the demand. The first-order condition gives $\theta_0^0 = \left(\bar{\theta} + \alpha/s_0\right)/2$.[3] The market price is equal to $p_h^0 = (\bar{\theta}s_0 + \alpha)/2$, producing a monopolist profit of $\pi_0^0 = (\bar{\theta}s_0 - \alpha)^2/(4s_0)$.

Note that this case exists when $\underline{\theta} < \theta_0^0$, or $2\underline{\theta} - \bar{\theta} < \alpha/s_0$. The portion of the market $[\underline{\theta}, \theta_0^0)$ is not served by the firm.

Case (B): $\underline{\theta} \geq (\bar{\theta} + \alpha/s_0)/2$

In this case, $\underline{\theta} \geq \theta_0^0$, and the monopolist prefers to serve the whole market. It will set the price of the product at $p_h^1 = \underline{\theta}s_0$, earning a profit of $\pi_h^1 = (\underline{\theta}s_0 - \alpha)(\bar{\theta} - \underline{\theta})$.

In the rest of the present paper, we consider only case B in which the monopolist, when alone in the market with a fixed quality level of its product, chooses to serve the whole market.

2.2 Product with Quality Determined Endogenously

Suppose that the monopolist is able to improve the quality of its product: By spending a cost of $c_h = c(e_h)$, the firm is able to improve the quality of the product by $e_h \in [0, \infty)$. The new quality level is $s_h = s_0 + e_h$.

[3] The profit function is strictly concave in θ_0, ensuring that the second-order condition is satisfied.

The quality improvement cost function satisfies the following conditions: (a) $c(0) = c'(0) = 0$; (b) $c(e_h)$, $c'(e_h) > 0$ for $e_h > 0$; (c) $c''(e_h) > 0$ for $e_h \geq 0$; (d) $c'(e_h)$ is sufficiently large when e_h is large. The last assumption is made to ensure that the firm will not want to choose a very large quality improvement value. A possible cost function c_h is illustrated in Figure 1.[4] With an improvement in the quality of the product, the monopolist still prefers to serve the whole market (case B). So it will set a price at $\underline{\theta} s_h = \underline{\theta}(s_0 + e_h)$. Its problem becomes

$$\max_{e_h} [\underline{\theta}(s_0 + e_h) - \alpha - c(e_h)](\bar{\theta} - \underline{\theta}).$$

The first-order condition is

$$c'(e_h) = \underline{\theta}. \tag{1}$$

A solution with $e_h \in (0, \infty)$ is guaranteed because the derivative of the profit function with respect to e_h is (a) positive at $e_h = 0$, and (b) negative when e_h is sufficiently large. Strict convexity of the cost function $c(e_h)$ implies that the the solution represents a maximum and is unique. The equilibrium quality improvement is depicted by point H in Figure 1, at which the slope of the cost function is equal to $\underline{\theta}$.

3 International Rivalry

Suppose now that export by the foreign firm to the home country is allowed. For the time being, no government interventions are considered so that free trade exists. Variables of the home (foreign) firm are distinguished by a subindex "h" ("f"). Assume again that the range of the market is not too big so that either or both of them will choose to serve the whole market.[5] Both firms have assess to the technology to produce the product of a quality level of $s_{0,}$ and both firms decide whether to improve the quality of their outputs by paying a cost.

We consider the following two-stage game. In stage one, firm i chooses to improve the quality of its output by $e_i \in [0, \infty)$, after paying a cost of c_i, where $c_h = c(e_h)$, $c_f = \lambda c(e_f)$, and $\lambda > 1$. The parameter λ is used to represent the inferior quality improvement technology possessed by the

[4]Ignore the curve labeled c_f for the time being.

[5]In other words, the condition for case B exists, $2\underline{\theta} - \bar{\theta} > \alpha/s_0$.

foreign firm.[6] The quality level of the firm i's output is equal to $s_i = e_i + s_0$, $i = h,\ f$. In the second stage, the firms compete in the home market in a Bertrand way, with the price set by firm i denoted by p_i. Consumers, taking the quality levels and prices set by the firms, choose the output from the firm that produces a higher utility level. For example, consumer θ will choose the output of the home (foreign) firm if $\theta s_h - p_h > (<)\ \theta s_f - p_f$. Let $\hat{\theta}$ by the consumer who is indifferent to the product produced by the firms, i.e., $\hat{\theta} s_h - p_h = \hat{\theta} s_f - p_f$. By rearranging the terms, we have

$$\hat{\theta} = \frac{p_h - p_f}{s_h - s_f}. \tag{2}$$

Thus the necessary and sufficient condition for both firms supplying a positive output to the market is

$$\underline{\theta} < \hat{\theta} < \bar{\theta}. \tag{3}$$

The demand functions for the home and foreign firms are as follows, respectively:

$$q_h = \bar{\theta} - \hat{\theta} \tag{4a}$$

$$q_f = \hat{\theta} - \underline{\theta}. \tag{4b}$$

For the time being, assume no government interventions, with the foreign firm freely exporting its output to the home market. The profit functions of the home and foreign firms are given as follows, respectively:

$$\pi_h = [p_h - \alpha - c(e_h)]q_h \tag{5a}$$

$$\pi_f = [p_f - \alpha - \lambda c(e_f)]q_f. \tag{5b}$$

To obtain a subgame perfect equilibrium, the two-stage game is solved by backward induction. Differentiate each firm's profit function in (5) by its own price, taking the other firm's price level and the quality levels as given. Solving the reaction functions, the second-stage equilibrium prices are

$$p_h = \alpha + \frac{1}{3}[2c(e_h) + \lambda c(e_f) + (2\bar{\theta} - \underline{\theta})(e_h - e_f)] \tag{6a}$$

$$p_f = \alpha + \frac{1}{3}[c(e_h) + 2\lambda c(e_f) - (2\underline{\theta} - \bar{\theta})(e_h - e_f)], \tag{6b}$$

[6] The technology gap may be due to more experience of the home firm. In general, firms tend to choose different quality levels of their products and the present assumption is one way to avoid symmetry between the firms.

and the resulting profits are

$$\pi_h = \frac{1}{9}(e_h - e_f)(2\bar{\theta} - \underline{\theta} - g)^2 \tag{7a}$$

$$\pi_f = \frac{1}{9}(e_h - e_f)(g - 2\underline{\theta} + \bar{\theta})^2, \tag{7b}$$

where $g = g(e_h, e_f, \lambda) = [c(e_h) - \lambda c(e_f)]/(e_h - e_f)$ for $e_h > 0$, $e_f \geq 0$. It is clear that because the foreign firm is inferior in quality improvement, in equilibrium we must have $e_h > e_f$, which is the case we will focus in this paper. The derivatives of $g(e_h, e_f)$ are

$$g_h \equiv \frac{\partial g}{\partial e_h} = \frac{c'(e_h) - g}{e_h - e_f} \tag{8a}$$

$$g_f \equiv \frac{\partial g}{\partial e_f} = \frac{g - \lambda c'(e_f)}{e_h - e_f} \tag{8b}$$

$$g_\lambda \equiv \frac{\partial g}{\partial \lambda} = -\frac{c(e_f)}{e_h - e_f}. \tag{8c}$$

To determine the signs of the derivatives in (8), refer to Figure 1, where $c_h = c(e_h)$ and $c_f = \lambda c(e_f)$. Suppose that the home and foreign have chosen e_h^1 and e_f^1, respectively. So $g(e_h, e_f, \lambda)$ is equal to the slope of line FH. Consider the following condition:

$$g > \lambda c'(e_f). \tag{9}$$

Lemma 1 *Suppose that condition (9) holds. Then*
(a) $g > 0$;
(b) $e_h > e_f$;
(c) $c(e_h) > \lambda c(e_f)$;
(d) g_h, $g_f > 0$, $g_\lambda < 0$.

Proof. Note that $c'(e_f) > 0$, part (a) follows immediately. Part (a) implies part (b), as evident from Figure 1. Part (c) comes from the definition of g and parts (a) and (b). Part (d) comes from conditions (8). ■

The usefulness of Lemma 1 is that, as will be shown later, if both firms are producing positive outputs, the output chosen by the foreign firm e_f must be small enough so that condition (9) holds.

Recall the marginal consumer given by (2). Using function $g(e_h, e_f, \lambda)$ and the price equations (6), the marginal consumer can also be defined as

$$\hat{\theta} = \frac{\bar{\theta} + \underline{\theta} + g}{3}. \tag{10}$$

The necessary and sufficient condition (3) for a duopoly equilibrium with positive outputs by both firms reduces to

$$2\underline{\theta} - \bar{\theta} < g < 2\bar{\theta} - \underline{\theta}. \tag{11}$$

We now turn to the first stage, in which the two firms choose quality levels to maximize their own profits. Define the following function:

$$\Theta(e_h, e_f; \lambda) = (2\bar{\theta} - \underline{\theta} - g)(2\bar{\theta} - \underline{\theta} - 2c'_h + g). \tag{12}$$

It is easy to show that the partial differentiation of home firm's profit function in (7a) with respect to e_h, taking e_f as given, is equal to $\Theta(e_h, e_f; \lambda)/9$. Thus the first-order condition is $\Theta(e_h, e_f; \lambda) = 0$, which, according to (12), implies two solutions,

$$\begin{aligned} 2\bar{\theta} - \underline{\theta} - 2c'_h + g &= 0 & (13a)\\ 2\bar{\theta} - \underline{\theta} - g &= 0. & (13b) \end{aligned}$$

Note that the solution in (13b) implies zero profit of the home firm. Use subindices to denote partial derivatives of function $\Theta(e_h, e_f; \lambda)$; for example, $\Theta_h \equiv \partial\Theta/\partial e_h$. The second derivative of the profit function with respect to e_h is equal to $\Theta_h/9$, where

$$\Theta_h = (2\bar{\theta} - \underline{\theta} - g)(g_h - 2c''_h) - g_h(2\bar{\theta} - \underline{\theta} - 2c'_h + g), \tag{14}$$

where $c'_h \equiv c'(e_h)$. For the solution given by (13b), equation (14) reduces to

$$\Theta_h = 2g_h(c'_h - g) > 0.$$

Suppose now that condition (13a) holds. Then $2\bar{\theta} - \underline{\theta} > g$, and

$$\Theta_h = (2\bar{\theta} - \underline{\theta} - g)(g_h - 2c''_h) < 0, \tag{15}$$

where the sign is due to the assumption that the quality improvement function $c(e_h)$ is sufficiently convex so that $2c''_h > g_h > 0$. Thus the solution in

(13b) gives a minimum and that in (13a) leads to a maximum. Thus we now assume that condition (13a) holds but not (13b). Condition (13a) gives the reaction function of the home firm, $e_h = R_h(e_f)$.

The same analysis can be applied to the foreign firm. Denote the partial derivative of the foreign firm's profit function (7b) with respect to e_f (keeping e_h constant) by $\Phi(e_h, e_f; \lambda)/9$, where

$$\Phi(e_h, e_f; \lambda) = (g - 2\underline{\theta} + \bar{\theta})(g + 2\underline{\theta} - \bar{\theta} - 2c'_f), \tag{16}$$

where $c'_f \equiv \lambda c'(e_f)$. The first-order condition is $\Phi(e_h, e_f; \lambda) = 0$. From (16), two roots exist:

$$g + 2\underline{\theta} - \bar{\theta} - 2c'_f = 0 \tag{17a}$$
$$g - 2\underline{\theta} + \bar{\theta} = 0. \tag{17b}$$

Following the same analysis given above, the root given by (17b) corresponds to a minimum, with the foreign firm earning zero profit. The solution corresponding to (17a) gives a maximum, as long as $g_f - 2c''_f < 0$.[7] Condition (17a) gives the foreign firm's reaction function $e_f = R_f(e_h)$, as long the foreign firm is making a positive profit.[8] At this maximum, (11) implies that $g > 2\underline{\theta} - \bar{\theta}$. Alternatively, we can say that if it is known that the foreign firm produces a positive output, (17a) implies that condition (9) is satisfied, and by Lemma 1, g_h, $g_f > 0$.

Thus, the Nash equilibrium with positive outputs by both firms can be described by the following conditions:

$$\Theta(e_h, e_f; \lambda) = 0 \tag{18}$$
$$\Phi(e_h, e_f; \lambda) = 0. \tag{19}$$

Using the derivatives of function g and the first-order conditions of the firms, we can show that $\Theta_f = \Phi_h = 2(e_h - e_f)g_h g_f > 0$. Denote the Nash equilibrium by (e_h^n, e_f^n), which satisfies conditions (18) and (19). Once the quality improvements chosen by the firms are determined, the market prices and firms' profits can be obtained from conditions (6) and (7). The Nash equilibrium, denoted by point N, occurs at the intersection point of the two schedules.

[7] The second-order condition is satisfied: $\Phi_f = (g - 2\underline{\theta} + \bar{\theta})(g_f - 2c''_f) < 0$.

[8] If the optimal quality improvement level and the corresponding output implied by (17a) lead to zero profit, the foreign firm is indifferent to this outcome and no production. In this case, we assume that the foreign firm will choose not to produce.

In the above analysis, it is assumed that both firms produce positive outputs of the product. In general, when the technology gap between the firms is not big, i.e., λ is only slightly greater than unity, the firms will share the market approximately equally. We now want to see what difference it will make if the technology gap becomes larger. Treating λ as a parameter, we increase it exogenously.

Lemma 2 *An increase in the technology gap between the firms will increase home firm's profit but lower foreign firm's profit. However, the impacts on the consumer surplus and home welfare are ambiguous.*

Proof. Differentiating equations (18) and (19) with respect to λ yields

$$\begin{bmatrix} \Theta_h & \Theta_f \\ \Phi_h & \Phi_f \end{bmatrix} \begin{bmatrix} \partial e_h^n/\partial\lambda \\ \partial e_f^n/\partial\lambda \end{bmatrix} = \begin{bmatrix} c(e_f)/(e_h - e_f) \\ 2c'(e_f) + [c(e_f)/(e_h - e_f)] \end{bmatrix}.$$

Solving these two equations, we get

$$\frac{\partial e_h^n}{\partial\lambda} = \frac{\partial s_h^n}{\partial\lambda} < 0 \tag{20}$$

$$\frac{\partial e_f^n}{\partial\lambda} = \frac{\partial s_f^n}{\partial\lambda} < 0 \tag{21}$$

Using (20), we have

$$\frac{\mathrm{d}\pi_h^n}{\mathrm{d}\lambda} = \frac{\partial\pi^n}{\partial\lambda} + \frac{\partial\pi_h^n}{\partial e_f}\frac{\partial e_f^n}{\partial\lambda} > 0, \tag{22}$$

because $\partial\pi_h^n/\partial\lambda = 2c(e_f^n)(\bar{\theta} - \hat{\theta})/3 > 0$, $\partial\pi_h^n/\partial e_f = -(\bar{\theta} - \underline{\theta})(\bar{\theta} - \hat{\theta}) < 0$ and $\partial e_f^n/\partial\lambda < 0$. We also have

$$\frac{\mathrm{d}\pi_f^n}{\mathrm{d}\lambda} = \frac{\partial\pi_f^n}{\partial\lambda} + \frac{\partial\pi_f^n}{\partial e_h}\frac{\partial e_h^n}{\partial\lambda} < 0, \tag{23}$$

because $\partial\pi_f^n/\partial\lambda = -2c(e_f^n)(\hat{\theta} - \underline{\theta})/3 < 0$, $\partial\pi_f^n/\partial e_h = (\bar{\theta} - \underline{\theta})(\hat{\theta} - \underline{\theta}) > 0$ and $\partial e_h^n/\partial\lambda < 0$.

$$\frac{\mathrm{d}CS^n}{\mathrm{d}\lambda} = \frac{\partial CS^n}{\partial\lambda} + \frac{\partial CS^n}{\partial e_h}\frac{\partial e_h^n}{\partial\lambda} + \frac{\partial CS^n}{\partial e_f}\frac{\partial e_f^n}{\partial\lambda},$$

where $\partial CS^n/\partial\lambda = c(e_f^n)(2\underline{\theta} - \bar{\theta} - \hat{\theta})/3 < 0$, $\partial CS^n/\partial e_h = (\bar{\theta} - \underline{\theta})(2\underline{\theta} - \bar{\theta} - \hat{\theta})/2 < 0$ and $\partial CS^n/\partial e_f = (\bar{\theta} - \underline{\theta})(2\bar{\theta} - \hat{\theta} - \underline{\theta})/2 > 0$. The direct effect of λ on consumer surplus is always negative, but the indirect effect is ambiguous because the opposite effects of high quality and low quality on consumer surplus. Thus, the overall effect of λ on consumer surplus is ambiguous a priori. Similarly, the overall effect of λ on the home welfare is ambiguous a priori. ■

Because of equation (23), let λ^c be the value of λ so that the resulting $\pi_f^n = 0$, i.e., the foreign firm would earn zero profit. It is thus indifferent to improving the quality of the product and producing nothing. As assumed, the foreign firm will choose to produce and export nothing. We can define the corresponding value of g as $g^c \equiv (e_h^n(\lambda^c), e_f^n(\lambda^c), \lambda^c)$.

The Nash equilibrium can be illustrated in a simple diagram. In Figure 2, schedule AB represents condition (18) and schedule CE represents condition (19). Their slopes are given by

$$\left.\frac{\partial e_h}{\partial e_f}\right|_{\mathrm{AB}} = -\frac{\Theta_f}{\Theta_h} > 0$$

$$\left.\frac{\partial e_h}{\partial e_f}\right|_{\mathrm{CE}} = -\frac{\Phi_f}{\Phi_h} > 0,$$

where the signs of the slopes are based on the analysis given above. The diagram shows the case in which schedule CE is steeper than AB.[9] The diagram also shows schedule HK, which represents $g(e_h, e_f, \lambda^c) = g^c$, i.e., the locus of (e_h, e_f) that, when $\lambda = \lambda^c$, will give a value of g equal to g^c. Schedules CE and HK intersect at point D.

Based on the above analysis, the reaction curve of the foreign firm is represented by the part of the vertical axis OF plus DC, the part of CE above schedule HK when the foreign firm is able to get a positive profit when reacting to the home firm's quality improvement. The resulting Nash equilibrium is at point N, at which DC and AB intersect.

The lemma can be illustrated in Figure 2. An increase in λ will shift schedule AB down and schedule CE to the left. Let the new schedules be AB′ and C′E′, respectively, intersecting at the new Nash equilibrium point N′, $(e_h^{n\prime}, e_f^{n\prime})$, with both firms making smaller quality improvement than before.

Since the Nash equilibrium depends on the value of λ, we can express the quality improvement levels chosen by the firms as the following functions

[9] This is the usual "stability" condition. While in the present one-shot game stability has no meaning, the present condition gives "normal" comparative static results.

$e_h^n = e_h^n(\lambda)$ and $e_f^n = e_f^n(\lambda)$, which depend negatively on λ. Graphically, if we increase λ gradually, the resulting Nash equilibria trace out a locus shown in Figure 3. Let us call this the *quality competition (QC) schedule*.[10]

Along the QC schedule, the change in function $g(e_h, e_f, \lambda)$ along the QC schedule is

$$\frac{\mathrm{d}g}{\mathrm{d}\lambda} = \frac{\partial g}{\partial e_h}\frac{\partial e_h}{\partial \lambda} + \frac{\partial g}{\partial e_f}\frac{\partial e_f}{\partial \lambda} + \frac{\partial g}{\partial \lambda} < 0.$$

Let λ^c be the value of λ so that $g^c = g(e_h^n(\lambda^c), e_f^n(\lambda^c), \lambda^c) = 2\underline{\theta} - \bar{\theta}$. Recall that with $g = g^c$, the profit of the foreign firm is zero. In Figure 3, schedule HK represents the equation $g(e_h, e_f, \lambda^c) = g^c$, which gives the combinations of the firms' quality improvement levels, when given λ^c, so that the value of g remains at g^c.[11]

However, when $\lambda = \lambda^c$, there is a strategy for the home firm to earn a profit more than what point N$'$ represents. What it should do, as the following proposition shows, is to regard itself as a monopolist, as Section 2.2 describes.

Proposition 1 *There exists a critical value λ^c so that if $\lambda < \lambda^c$, an international duopoly equilibrium exists with both firms earning positive profits. If $\lambda \geq \lambda^c$, then the home firm will behave as a local monopolist, with zero import from the foreign firm.*

Proof. We have already analyzed the case in which $\lambda < \lambda^c$. When $\lambda = \lambda^c$, the foreign firm earns zero profit at the Nash equilibrium, and we assume that it will choose not to enter the market. When $\lambda > \lambda^c$, the foreign firm earns negative profit at a Nash equilibrium, and it is better off by not entering the market. As for the home firm, when $\lambda \geq \lambda^c$, the home firm can choose the monopolistic equilibrium, which will give it the highest possible profit. It does not have to worry about the possible entry of the foreign firm as it will get negative profit if it does try to enter the market. ■

[10] The quality competition schedule is defined by the two parametric equations: $e_h^n = e_h^n(\lambda)$ and $e_f^n = e_f^n(\lambda)$. By lemma 2, it is positively sloped, and the value of λ increases along the schedule toward the vertical axis.

[11] There may be a question of whether the QC schedule and schedule HK do not cut each other at a point when e_h and e_f are non-negative. The answer is in the negation because if $g > g^c$, then when $e_f = 0$, $c'(e_f) = 0$ and π^f is increasing in e_f. This means that when $g > g^c$, the foreign firm will want to improve its output quality, and QC schedule will not cut the vertical axis first before cutting schedule HK.

4 Minimum Quality Standard

In this section, we analyze the use of a minimum quality standard (MQS) policy by the foreign government while the home government still allows free trade. We want to analyze how the foreign government may use this policy to improve its national welfare, and how it may hurt the home country.

We assume that the foreign government is able to announce and pre-commit a policy before the firms compete. To do so, we extend the model introduced above to a three-stage model. The second and third stages are similar to the two stages in the previous model, with the firms competing in quality and then in price. In the first stage the foreign government sets a MQS for the output of the foreign firm, $\bar{s}_f$. In other words, the foreign firm has to produce an output of quality not less than $\bar{s}_f$ before the product is allowed to be exported. For a reasonable analysis in this section, λ is assumed to be not so great so that an international duopoly exists with or without the government policy.

As usual, the game is solved by backward induction. Because the present second and third stages are the same as the two stages of the previous model, except that the quality level of the foreign output is $\bar{s}_f$, we can focus on the first stage.[12] In this stage, the foreign government choose a MQS $\bar{s}_f$ to maximize the national welfare, which consists of the foreign firm's profits, making use of the reaction function of the home firm, $R_h(s_f)$.[13] Differentiate the foreign firm's profit function with respect to the quality level to get:

$$\begin{aligned}
\frac{\mathrm{d}\pi_f}{\mathrm{d}s_f} &= \frac{\partial \pi_f}{\partial s_f} + \frac{\partial \pi_f}{\partial s_h}\frac{\partial R_h(s_f)}{\partial s_f} \\
&= \frac{1}{9}(g - 2\underline{\theta} + \bar{\theta})[2\underline{\theta} - \bar{\theta} - 2\lambda c'(e_f) + g] \\
&\quad + \frac{1}{9}(g - 2\underline{\theta} + \bar{\theta})[2c'(e_h) - g - 2\underline{\theta} + \bar{\theta}]\frac{\partial R_h(s_f)}{\partial s_f} \\
&= \frac{1}{9}(g - 2\underline{\theta} + \bar{\theta})\left[2c'(e_h) - 2\lambda c'(e_f) - 3(\bar{\theta} - \underline{\theta})\left(1 - \frac{\partial R_h(s_f)}{\partial s_f}\right)\right] \qquad (24)
\end{aligned}$$

Note that $\partial R_h(s_f)/\partial s_f$ is the slope of schedule CDE in Figure 2. Evaluate

[12] As will be explained later, the MQS chosen by the foreign government will be higher than the Nash s_f chosen by the foreign firm so that the MQS is binding.

[13] The home firm's reaction function is defined in (13a).

the derivative in (24) at the free-trade Nash equilibrium to give

$$\left.\frac{\mathrm{d}\pi_f}{\mathrm{d}s_f}\right|_{s_f=s_f^n} = \frac{\partial \pi_f}{\partial s_h}\frac{\partial R_h(s_f)}{\partial s_f} = \frac{1}{3}(\bar{\theta}-\underline{\theta})(g-2\underline{\theta}+\bar{\theta})\frac{\partial R_h(s_f)}{\partial s_f} > 0. \qquad (25)$$

Condition (25) implies that the foreign government has an incentive to impose a MQS at least slightly higher than the free trade level. Because the quality improvement cost becomes prohibitively high when e_f is large, the foreign government will never want to impose a MQS too high. Thus we conclude that the optimal MQS for the foreign country is finite and higher than the free-trade level. At the maximum, $\mathrm{d}\pi_f/\mathrm{d}s_f = 0$, which, by condition (25), implies[14]

$$\partial R_h(s_f)/\partial s_f < 1. \qquad (26)$$

It is easy to check that $\mathrm{d}q_f/\mathrm{d}s_f > 0$ and $\mathrm{d}q_h/\mathrm{d}s_f < 0$. Thus, the MQS increases the volume of exports to the home market while reduces the sales volume of the domestic good. Differentiate the home profit with respect to the MQS to give,

$$\frac{\mathrm{d}\pi_h}{\mathrm{d}s_f} = \frac{\partial \pi_h}{\partial s_h}\frac{\partial R_h(s_f)}{\partial s_f} + \frac{\partial \pi_h}{\partial s_f} = \frac{\partial \pi_h}{\partial s_f} < 0. \qquad (27)$$

Condition (27) implies that the home firm is hurt by the MQS.

From equation (24), it is easy to see how the MQS works: It moves the equilibrium is moved from the free-trade Nash equilibrium to the Stackelberg point, as the foreign firm acting as if it is a leader. Without any government intervention, the foreign firm can hardly achieve this equilibrium because any attempt to convince the home firm to produce an output with a higher standard is not credible, but now with the MQS, an announcement by the foreign firm to produce an output with a higher standard becomes credible. Such a policy to help the foreign firm get a higher profit in the presence of international rivalry is similar to the Brander-Spencer type export subsidies (Brander and Spencer, 1985), as both have the effect of shifting (part of) the home firm's profit to the foreign firm. However, two differences between the present policy and the Brander-Spencer type export subsidies can be noted: MQS does not appear to be a trade policy, and due to the asymmetry

[14] Note that in (24), $g > 2\underline{\theta} - \bar{\theta}$ and $c'(e_h) > \lambda c'(e_f)$.

between the two firms, MQS does not work for the home country.[15]

The impact of the MQS $\bar{s}_f$ on consumer surplus in the home country is

$$\begin{aligned}
\frac{\mathrm{d}CS_h}{\mathrm{d}s_f} &= \frac{\partial CS_h}{\partial s_h}\frac{\partial R_h(s_f)}{\partial s_f} + \frac{\partial CS_h}{\partial s_f} \\
&= \frac{1}{2}(\bar{\theta} - \underline{\theta})[(2\underline{\theta} - \bar{\theta} - \hat{\theta})\frac{\partial R_h(s_f)}{\partial s_f} + (2\bar{\theta} - \hat{\theta} - \underline{\theta})] \\
&> \frac{1}{2}(\bar{\theta} - \underline{\theta})(\bar{\theta} + \underline{\theta} - 2\hat{\theta}) \\
&> 0,
\end{aligned} \tag{28}$$

where the first inequality in equation (28) comes from the assumption (26)and the second inequality in equation (28) comes from the fact that $\hat{\theta} < (\bar{\theta}+\underline{\theta})/2$. Thus, a foreign MQS always benefits the home consumers.[16] The total effect of the MQS on the home welfare is

$$\begin{aligned}
\frac{\mathrm{d}W_h}{\mathrm{d}s_f} &= \frac{\partial CS_h}{\partial s_h}\frac{\partial R_h(s_f)}{\partial s_f} + \frac{\partial CS_h}{\partial s_f} + \frac{\partial \pi_h}{\partial s_f} \\
&= \frac{1}{2}(\bar{\theta} - \underline{\theta})[(2\underline{\theta} - \bar{\theta} - \hat{\theta})\frac{\partial R_h(s_f)}{\partial s_f} + (\hat{\theta} - \underline{\theta})] \\
&= \frac{1}{2}(\bar{\theta} - \underline{\theta})\left[(\hat{\theta} - \underline{\theta}) - (\bar{\theta} + \hat{\theta} - 2\underline{\theta})\frac{\partial R_h(s_f)}{\partial s_f}\right].
\end{aligned} \tag{29}$$

The sign of $\mathrm{d}W_h/\mathrm{d}s_f$ is in general ambiguous and depends on, among other things, the value of $\partial R_h(s_f)/\partial s_f$. We have the following proposition:

Proposition 2 *When the home country imports the low-quality good, a MQS on the imports benefits the home country if the marginal cost function is weakly convex, i.e., $c'''(e_i) \geq 0$.*

[15] With a given market, the foreign firm wants the home firm to choose a higher standard of its output so that it can have an output with a higher quality in order to capture a bigger share of the market. Conversely, the home firm wants the foreign firm to choose a lower quality so that it can capture a bigger share of the market.

[16] With cost advantage, the home firm producing the higher quality product must earn higher profits than the foreign firm producing the lower quality product, otherwise the former can always get higher profits than the latter's duopoly profits by deviating to produce the lower quality product instead. Thus, $9\pi_h = (e_h - e_f)(2\bar{\theta} - \underline{\theta} - g)^2 > (e_h - e_f)(\bar{\theta} - 2\underline{\theta} + g)^2 = 9\pi_f$, implying that $g < \frac{1}{2}(\bar{\theta} + \underline{\theta})$ and $\hat{\theta} = (\bar{\theta} + \underline{\theta} + g)/3 < (\bar{\theta} + \underline{\theta})/2$.

Proof. *Since* $g = 2c'(e_h) + \underline{\theta} - 2\bar{\theta}$,

$$\frac{(\hat{\theta} - \underline{\theta})}{(\bar{\theta} + \hat{\theta} - 2\underline{\theta})} = \frac{\bar{\theta} - 2\underline{\theta} + g}{4\bar{\theta} - 5\underline{\theta} + g} = \frac{c'(e_h) - (\bar{\theta} + \underline{\theta})/2}{c'(e_h) + \bar{\theta} - 2\underline{\theta}}.$$

From equation (24), we know that $c'(e_h) - \lambda c'(e_f) = \frac{3}{2}(\bar{\theta} - \underline{\theta})(1 - \partial R_h(s_f)/\partial s_f)$. *Thus*

$$\begin{aligned}
\frac{\partial R_h(s_f)}{\partial s_f} &= \frac{(\partial g/\partial s_f)}{2c''(e_h) - (\partial g/\partial s_h)} \\
&= \frac{g - \lambda c'(e_f)}{2c''(e_h)(e_h - e_f) - c'(e_h) + g} \\
&= \frac{c'(e_h) - \lambda c'(e_f) + c'(e_h) + \underline{\theta} - 2\bar{\theta}}{2c''(e_h)(e_h - e_f) + c'(e_h) + \underline{\theta} - 2\bar{\theta}} \\
&= \frac{3(\bar{\theta} - \underline{\theta})(1 - \partial R_h(s_f)/\partial s_f)/2 + c'(e_h) + \underline{\theta} - 2\bar{\theta}}{2c''(e_h)(e_h - e_f) + c'(e_h) + \underline{\theta} - 2\bar{\theta}}.
\end{aligned}$$

With some mathematical operations, we can get

$$\frac{\partial R_h(s_f)}{\partial s_f} = \frac{c'(e_h) - (\bar{\theta} + \underline{\theta})/2}{2c''(e_h)(e_h - e_f) + c'(e_h) - (\bar{\theta} + \underline{\theta})/2}.$$

From equation (29), $dW_h/ds_f > 0$ *if* $(\hat{\theta} - \underline{\theta})/(\bar{\theta} + \hat{\theta} - 2\underline{\theta}) > \partial R_h(s_f)/\partial s_f$, *i.e.,* $2c''(e_h) > 3(\bar{\theta} - \underline{\theta})/2(e_h - e_f)$. *This condition is satisfied if* $c'''(e_i) \geq 0$, *because*

$$2c''(e_h) > \frac{2(c'(e_h) - \lambda c'(e_f))}{e_h - e_f} = \frac{3(\bar{\theta} - \underline{\theta})}{(e_h - e_f)}\left(1 - \frac{\partial R_h(s_f)}{\partial s_f}\right) > \frac{3}{2}\frac{(\bar{\theta} - \underline{\theta})}{(e_h - e_f)},$$

where the last inequality comes from the fact that $c''(e_h) > [c'(e_h) - \lambda c'(e_f)]/(e_h - e_f) = \partial G/\partial e_h + \partial G/\partial e_f$, *implying that*

$$\frac{\partial R_h(s_f)}{\partial s_f} = \frac{\partial G/\partial e_f}{2c''(e_h) - \partial G/\partial e_h} < \frac{c''(e_h) - \partial G/\partial e_h}{2c''(e_h) - \partial G/\partial e_h} < \frac{1}{2}.$$

■

Under the duopoly model in a closed economy, Crampes and Hollander (1995) show that if the quality response by the high-quality firm is less than the increase in quality by the low-quality firm (i.e., $\partial R_h(s_f)/\partial s_f < 1$ in our notation), a MQS will increase social welfare. However, when we consider an open economy in which the foreign firm exports to the home country, the necessary (but not sufficient) condition to make the MQS increase the home welfare is $\partial R_h(s_f)/\partial s_f < 1/3$, which is much stricter.[17]

Comparing our results with Das and Donnenfeld (1989), one can find two differences: 1. The sales by the home firm decrease while the sales by the foreign firm increase. However, a MQS reduces both firms' sales in Das and Donnenfeld (1989). 2. The effect of a MQS on the home welfare is positive if the marginal cost function is weakly convex in our model. However, a MQS always hurts the home country in Das and Donnenfeld (1989).

Proposition 2 provides the circumstances that the home country may benefit from the foreign government's MQS policy. In fact, it also implies that the home government can increase its welfare by setting a MQS on the imports if the foreign government does not take any MQS policy and if the marginal cost function is weakly convex. However, in Das and Donnenfeld (1989), the home government has no incentive to adopt a MQS policy because it always hurts the home country. In the real word, many exporting and importing countries do adopt the MQS policies. Thus, our model is better to accord with the real observations and to justify the MQS policy.

5 Minimum Quality Standard and Tariff

As explained, a MQS imposed by the foreign government has an adverse effect on the profit of the home firm. This can be used as a reason for imposing a tariff on the imported foreign product. It is well known that tariff is a policy to shift profit from the foreign monopolist to a domestic firm. It is thus a policy that can be used as a counteracting policy to protect the domestic firm. This section examines the interactions between the two governments when trying to protect their own firms. Two cases are considered: the case in which both governments choose their policies simultaneously, and the case

[17] From footnote 14 we know that $\hat{\theta} < \frac{1}{2}(\bar{\theta} + \underline{\theta})$. $\mathrm{d}W_h^*/\mathrm{d}s_f > 0$ if $[(\hat{\theta} - \underline{\theta})/(\bar{\theta} + \hat{\theta} - 2\underline{\theta})] > \partial R_h(s_f)/\partial s_f$. Since $[(\hat{\theta} - \underline{\theta})/(\bar{\theta} + \hat{\theta} - 2\underline{\theta})] = [(\hat{\theta} - \underline{\theta})/(\bar{\theta} - \underline{\theta}) + (\hat{\theta} - \underline{\theta})] = [(\bar{\theta} - \underline{\theta})/(\hat{\theta} - \underline{\theta}) + 1]^{-1} < \frac{1}{3}$, $\partial R_h(s_f)/\partial s_f < \frac{1}{3}$ is a necessary (but not sufficient) condition for a foreign MQS benefitial to the home country.

in which the foreign government takes the first move.

5.1 Simultaneous Policies

We now modify the above three-stage game. In the first stage, the foreign government chooses MQS and the home government chooses a tariff at the same time. In the second stage, taking the policy parameters as given, both firms choose the quality and then in the third stage they choose the prices. As usual, the third period is solved first. The profits of the firms can be written as:

$$\pi_h^t = [p_h - \alpha - c(e_h)]q_h \tag{30a}$$
$$\pi_f^t = [p_f - t - \alpha - \lambda c(e_f)]q_f, \tag{30b}$$

where superscript "t" is used to represent variables in this case with a tariff. Following the steps explained above, differentiate each firm's profit function by its price and solve the equations to give[18]

$$p_h^t = \alpha + \frac{1}{3}\left[2c(e_h) + \lambda c(e_f) + (2\bar{\theta} - \underline{\theta})(e_h - e_f) + t\right] \tag{31a}$$
$$p_f^t = \alpha + \frac{1}{3}[c(e_h) + 2\lambda c(e_f) + (\bar{\theta} - 2\underline{\theta})(e_h - e_f) + 2t]. \tag{31b}$$

The resulting profit functions of the firms are

$$\pi_h^t = \frac{1}{9}(e_h - e_f)(2\bar{\theta} - \underline{\theta} - G)^2 \tag{32a}$$
$$\pi_f^t = \frac{1}{9}(e_h - e_f)(\bar{\theta} - 2\underline{\theta} + G)^2, \tag{32b}$$

where $G = [c(e_h) - \lambda c(e_f) - t]/(e_h - e_f)$ for $e_h > e_f \geq 0$. The first-order conditions in the second stage are

$$2\bar{\theta} - \underline{\theta} - 2c'(e_h) + G = 0 \tag{33a}$$
$$2\underline{\theta} - \bar{\theta} - 2\lambda c'(e_f) + G = 0. \tag{33b}$$

Again, assume that the following second-order conditions holds:

$$e_{11} \equiv 9\partial^2\pi_h^t/\partial e_h^2 = 2(e_h - e_f)(\partial G/\partial e_h)[(\partial G/\partial e_h) - 2c''(e_h)] < 0$$
$$e_{22} \equiv 9\partial^2\pi_f^t/\partial e_f^2 = 2(e_h - e_f)(\partial G/\partial e_f)[(\partial G/\partial e_f) - 2\lambda c''(e_f)] < 0.$$

[18] The second-order conditions are assumed to hold.

Furthermore, note that $e_{12} \equiv 9\partial^2\pi_h^t/\partial e_h\partial e_f = 9\partial^2\pi_f^t/\partial e_h\partial e_f \equiv e_{21} = 2(e_h - e_f)(\partial G/\partial e_h)(\partial G/\partial e_f) > 0$. In addition, it is assumed that $H = e_{11}e_{22} - e_{12}e_{21} > 0$, the usual "stability" condition. Equations (33a) and (33b) provide the reaction functions of the home and foreign firms, which can be alternatively denoted as $R_h(s_f, t)$ and $R_f(s_h, t)$, respectively. Note that $\partial R_h(s_f, t)/\partial s_f = -e_{12}/e_{11} > 0$, $\partial R_f(s_h, t)/\partial s_h = -e_{21}/e_{22} > 0$. Solving conditions (33) gives the equilibrium qualities, which are denoted by $(s_h^t(t), s_f^t(t))$. Note that $(s_h^t(t = 0), s_f^t(t = 0)) = (s_h^n, s_f^n)$, the free-trade Nash equilibrium derived in the previous section.

In this stage, both firms take the policy parameters as given. It is interesting to see how the quality levels of the firms' outputs are affected by a home tariff, if initially there is no MQS. Differentiating equations (33) with respect to t yields

$$\begin{bmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{bmatrix} \begin{bmatrix} \partial s_h^t/\partial t \\ \partial s_f^t/\partial t \end{bmatrix} = \begin{bmatrix} 2(\partial G/\partial e_h) \\ 2(\partial G/\partial e_f) \end{bmatrix}.$$

Solving these two equations, we get

$$\frac{\partial s_f^t}{\partial t} = \frac{-2c''(e_h)}{(e_h - e_f)H} < 0 \tag{34a}$$

$$\frac{\partial s_h^t}{\partial t} = \frac{-2\lambda c''(e_f)}{(e_h - e_f)H} < 0. \tag{34b}$$

Conditions (34) show that if there is no MQS a home tariff discourages the quality levels of both domestic and foreign goods.

Substituting $R_h(\bar{s}_f^t, t)$ into equation (32b), we get $\pi_f^t(\bar{s}_f^t, t)$ as a function of $\bar{s}_f^t$ and t. In the first stage, the foreign government chooses $\bar{s}_f^t$ to maximize $\pi_f^t(\bar{s}_f^t, t)$, taking the specific tariff t as given. The first-order condition is

$$\frac{\mathrm{d}\pi_f^t(\bar{s}_f^t, t)}{\mathrm{d}s_f} = \frac{\partial \pi_f^t}{\partial s_f} + \frac{\partial \pi_f^t}{\partial s_h}\frac{\partial R_h(s_f, t)}{\partial s_f} = 0, \tag{35}$$

which gives the reaction function of the foreign government, $\bar{s}_f^t(t)$, in terms of t.

To see how an interior solution for the foreign government exists, note that

$$\left.\frac{\mathrm{d}\pi_f^t}{\mathrm{d}s_f}\right|_{s_f = s_f^t} = \frac{\partial \pi_f^t}{\partial s_h}\frac{\partial R_h(s_f, t)}{\partial s_f} > 0.$$

This implies that the foreign government still has an incentive to impose MQS, even in the presence of a home tariff. The second-order condition $\mathrm{d}^2\pi_f^t/\mathrm{d}s_f^2 < 0$ is assumed to be satisfied. The slope of the reaction function $\bar{s}_f^t(t)$ is given by

$$\frac{\partial \bar{s}_f^t}{\partial t} = -\frac{\mathrm{d}^2\pi_f^t/\mathrm{d}s_f\mathrm{d}t}{\mathrm{d}^2\pi_f^t/\mathrm{d}s_f^2} < 0, \tag{36}$$

because $\mathrm{d}^2\pi_f^t/\mathrm{d}s_f\mathrm{d}t < 0$.[19] Condition (36) means that the level of the MQS decreases as the home tariff increases. Moreover, a specific tariff always has the effect to reduce both quality and quantity of the imports no matter whether the foreign government sets a MQS or not, i.e., $\bar{s}_f^t(t) < \bar{s}_f^t(t=0) = \bar{s}_f$ if the foreign government is active and $s_f^t(t) < s_f^t(t=0) = s_f^n$ if it is not. This result is different from Krishna (1987), indicating that a specific tariff raises quality and lowers imports when the marginal customer with higher willingness to pay has a higher valuation of an increment in quality.[20] Since the MQS raises both quality levels while the tariff reduces them, whether the equilibrium quality levels $(R_h(\bar{s}_f^t(t), t),\ \bar{s}_f^t(t))$ are higher than the benchmark equilibrium quality levels $(s_h^n,\ s_f^n)$ or not will depend on the level of t.

Before we consider the home government's optimal tariff policy, we need to derive the prohibitive tariff level which would deter the entry of the foreign firm. The prohibitive tariff is the one to make the foreign firm's duopoly market share just down to zero, i.e., $G = 2\underline{\theta} - \bar{\theta}$. From equation (33a), when $G = 2\underline{\theta} - \bar{\theta}$, $c'(e_h) = (\bar{\theta} + \underline{\theta})/2$. Let $\underline{e_h} = c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$. Given a certain level of MQS $\bar{s}_f^t = \bar{e}_f^t + s_0$, the prohibitive tariff is $t_p = c(\underline{e_h}) - \lambda c(\bar{e}_f^t) - (2\underline{\theta} - \bar{\theta})(\underline{e_h} - \bar{e}_f^t)$. When $t \in [0, t_p)$, entry is accommodated and a duopoly equilibrium of quality levels $(R_h(\bar{s}_f^t, t),\ \bar{s}_f^t)$ exists.

If $t_p < \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t)$ and $t \in [t_p, \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t))$, entry is deterred but not blockaded because $(\alpha + \lambda c(\bar{e}_f^t) + t)/\bar{s}_f^t < \underline{\theta}$. With the credible threat of entry by the foreign firm to produce $\bar{s}_f^t$ with the minimum price $\alpha + \lambda c(\bar{e}_f^t) + t$, the home firm has to set a price $p_h^d = \alpha + \lambda c(\bar{e}_f^t) + t + \underline{\theta}(e_h^d - \bar{e}_f^t)$ (where d stands for entry deterrence) if it chooses to improve the quality by e_h^d in

[19] See Appendix A for a proof.

[20] In our model, the valuation of an increment in quality by the customers buying the domestic (foreign) goods is $\partial p_h/\partial s_h = \hat{\theta} + \bar{\theta} - \underline{\theta}$ ($\partial p_f/\partial s_f = \hat{\theta} + \underline{\theta} - \bar{\theta}$), both increase as $\hat{\theta}$ increases. Thus, the marginal customer indexed by $\hat{\theta}$ with higher willingness to pay has a higher valuation of an increment in quality no matter whether he purchases the domestic or foreign goods.

order to make $\hat{\theta} = \underline{\theta}$. Thus, the home firm's optimization problem is

$$\max_{e_h^d} (\lambda c(\bar{e}_f^t) + t + \underline{\theta}(e_h^d - \bar{e}_f^t) - c(e_h^d))(\bar{\theta} - \underline{\theta}).$$

The first-order condition is $\underline{\theta} - c'(e_h^d) = 0$, and $e_h^d = c'^{-1}(\underline{\theta})$. When $t \geq \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t)$, entry is blockaded because $(\alpha + \lambda c(\bar{e}_f^t) + t)/\bar{s}_f^t \geq \underline{\theta}$. The home firm can maintain its pure monopoly position to choose the monopoly price p_h^m and quality s_h^m such that $p_h^m/s_h^m \leq \underline{\theta}$. (where m stands for monopoly). Thus, the optimization problem for the home monopolist is $\max(p_h^m - \alpha - c(e_h^m))(\bar{\theta} - \underline{\theta})$, s.t. $\underline{\theta}s_h^m - p_h^m \geq 0$. Solving the problem by backward induction, we get the second-stage optimal monopoly price $p_h^m = \underline{\theta}s_h^m = \underline{\theta}(s_0 + e_h^m)$ and the first-stage optimal improvement in quality $e_h^m = c^{'-1}(\underline{\theta})$.

If $t_p \geq \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t)$ and when $t \geq t_p$, entry is always blockaded because $(\alpha + \lambda c(\bar{e}_f^t) + t)/\bar{s}_f^t \geq \underline{\theta}$. Thus, the optimal improvement in quality $e_h^m = c^{'-1}(\underline{\theta})$ and the optimal monopoly price $p_h^m = \underline{\theta}s_h^m = \underline{\theta}(s_0 + e_h^m)$. In sum, as long as the tariff is set above the prohibitive level t_p, the home firm always chooses $e_h = c'^{-1}(\underline{\theta})$.[21] One interesting thing to note is that the home government has an incentive to impose a MQS on its domestic product under autarky. Under autarky, the home welfare equals $(\bar{\theta} - \underline{\theta})[\frac{1}{2}(\bar{\theta} + \underline{\theta})(s_0 + e_h) - \alpha - c(e_h)]$. Thus, the socially optimal improvement quality is $c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$, which is higher than $c'^{-1}(\underline{\theta})$. By imposing the MQS $\bar{s}_h = s_0 + c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$ on its domestic product, the home government can force the home firm to produce the socially optimal quality level to maximize the social welfare.

Lemma 3 *When the home government imposes a specific tariff above the prohibitive tariff level, the autarkic quality of the domestic product is always* $s_0 + c'^{-1}(\underline{\theta})$. *However, the home welfare under autarky is maximized when the quality of the domestic product equals* $s_0 + c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$. *Thus, the home welfare itself has the incentive to impose a MQS* $\bar{s}_h = s_0 + c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$ *under autarky.*

Lemma 3 actually shows that the autarkic quality of the domestic product is always equal to $s_0 + c'^{-1}(\underline{\theta})$ (if there is no domestic MQS policy), no matter

[21] Even though $e_h^m = e_h^d = c^{'-1}(\underline{\theta})$, the pure monopoly price p_h^m when entry is blockaded is higher than p_h^d when entry is deterred because $p_h^m - p_h^d = \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t) - t > 0$, .where $t \in [t_p, \underline{\theta}\bar{s}_f^t - \alpha - \lambda c(\bar{e}_f^t))$. Thus, $\pi_h^m > \pi_h^d$. However, consumer surplus is lower when entry is blockaded than when entry is deterred, and the home welfare is the same under both cases.

the entry deterrence is due to the home firm's cost advantage ($\lambda \geq \lambda^c$) or the home government's trade policy ($t \geq t_p$).

Now back to the home's optimal tariff policy. The home welfare, which is defined as $W_h^t = \pi_h^t + CS^t + tq_f^t$, is a function of $\bar{s}_f^t$ and t. Taking the foreign government's MQS $\bar{s}_f^t$ as given, the home government chooses a specific tariff t to maximize the home welfare. The first-order condition is

$$\begin{aligned}
\frac{\mathrm{d}W_h^t(\bar{s}_f^t, t)}{\mathrm{d}t} &= \frac{\partial \pi_h^t}{\partial t} + \frac{\partial CS^t}{\partial t} + \frac{\partial CS^t}{\partial s_h}\frac{\partial R_h(s_f, t)}{\partial t} + q_f^t \\
&\quad + t(\frac{\partial q_f^t}{\partial t} + \frac{\partial q_f^t}{\partial s_h}\frac{\partial R_h(s_f, t)}{\partial t}) \\
&= \frac{(\bar{\theta} - \underline{\theta})[2c''(e_h)(e_h - e_f) + 2c'(e_h) - (\bar{\theta} + \underline{\theta})] - 2c''(e_h)t}{3[2c''(e_h)(e_h - e_f) + c'(e_h) - (2\bar{\theta} - \underline{\theta})]} \\
&= 0. \qquad (37)
\end{aligned}$$

Thus, we can express the optimal tariff as

$$t^* = (\bar{\theta} - \underline{\theta})\left[(e_h - e_f) + \frac{2c'(e_h) - \bar{\theta} - \underline{\theta}}{2c''(e_h)}\right]. \qquad (38)$$

The second-order condition $\mathrm{d}^2W_h^t/\mathrm{d}t^2 < 0$ is satisfied as long as $c'''(e_i)$ is small enough.[22] Equation (37) provides the reaction function of the home government $t(\bar{s}_f^t)$, and its slope is given by

$$\frac{\partial t}{\partial \bar{s}_f^t} = -\frac{\mathrm{d}^2W_h^t/\mathrm{d}t\mathrm{d}s_f}{\mathrm{d}^2W_h^t/\mathrm{d}t^2}.$$

The sign of $\mathrm{d}^2W_h^t/\mathrm{d}t\mathrm{d}s_f$ is ambiguous. If $c'''(e_i) \geq 0$, $\partial t/\partial \bar{s}_f^t < 0$,[23] meaning that the optimal tariff decreases as the level of MQS increases. Thus, if $c'''(e_i) \geq 0$, we know that $\bar{s}_f^t$ and t are strategic substitutes. It can be shown that $\mathrm{d}W_h^t/\mathrm{d}t(t = 0) > 0$, implying that at least a small positive tariff is welfare improving. Assume that an interior solution ($\bar{s}_f^t$, t^*) exists by solving equations (35) and (37) simultaneously. Moreover, additional conditions to make sure that t^* is the optimal tariff in equilibrium is that $\mathrm{d}W_h^t/\mathrm{d}t(t = t_p) < 0$. That is, the optimal tariff t^* is below the prohibitive tariff t_p. However, if $\mathrm{d}W_h^t/\mathrm{d}t(t = t_p) > 0$, the home government will set the prohibitive tariff to

[22] See Appendix B for a proof.
[23] See Appendix C for a proof.

ban imports. Recall that $t_p = c(\underline{e_h}) - \lambda c(\bar{e}_f^t) - (2\underline{\theta} - \bar{\theta})(\underline{e_h} - \bar{e}_f^t)$, taken $\bar{e}_f^t$ as given..Evaluating the numerator in equation (37) at $t = t_p$, $e_h = \underline{e_h}$ and $e_f = \bar{e}_f^t$, we get

$$\begin{aligned}
& (\bar{\theta} - \underline{\theta})[2c''(\underline{e_h})(\underline{e_h} - \bar{e}_f^t) + 2c'(\underline{e_h}) - (\bar{\theta} + \underline{\theta})] - 2c''(\underline{e_h})t_p \\
= \; & 2(\bar{\theta} - \underline{\theta})c''(\underline{e_h})(\underline{e_h} - \bar{e}_f^t) - 2c''(\underline{e_h})[c(\underline{e_h}) - \lambda c(\bar{e}_f^t) - (2\underline{\theta} - \bar{\theta})(\underline{e_h} - \bar{e}_f^t)] \\
= \; & 2\underline{\theta}c''(\underline{e_h})(\underline{e_h} - \bar{e}_f^t) - 2c''(\underline{e_h})[c(\underline{e_h}) - \lambda c(\bar{e}_f^t)] \\
= \; & 2c''(\underline{e_h})(\underline{e_h} - \bar{e}_f^t)\left[\underline{\theta} - \frac{c(\underline{e_h}) - \lambda c(\bar{e}_f^t)}{\underline{e_h} - \bar{e}_f^t}\right]. \qquad (39)
\end{aligned}$$

Thus, the sign of $\mathrm{d}W_h^t/\mathrm{d}t(t = t_p)$ depends on the sign of $\underline{\theta} - [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$, which is indeterminate. If $\underline{\theta} < [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$, then $\mathrm{d}W_h^t/\mathrm{d}t(t = t_p) < 0$ and the optimal tariff is t^* as solved in equation (38). However, if $\underline{\theta} \geq [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$, $\mathrm{d}W_h^t/\mathrm{d}t(t = t_p) \geq 0$ and the optimal tariff is t_p. In fact, the sign of $\underline{\theta} - [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$ depends on the value of λ and $\bar{e}_f^t$. If λ is big, there is no way for the foreign government to set a MQS $\bar{e}_f^t$ to make $\underline{\theta} < [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$, so the optimal tariff for the home country is always the prohibitive tariff. Thus, the foreign government is unable to avoid a prohibitive tariff by using the MQS policy if the cost disadvantage of its firm is too big. On the other hand, if λ is small, the foreign firm can choose a $\bar{e}_f^t$ to make $\underline{\theta} < [c(\underline{e_h}) - \lambda c(\bar{e}_f^t)]/(\underline{e_h} - \bar{e}_f^t)$ so that the optimal tariff is below the prohibitive tariff to allow trade. Thus, the foreign MQS policy could be an effective instrument to reduce the tariff if the cost disadvantage of the foreign firm is small enough.

Proposition 3 *When the foreign firm produces the low-quality good, the foreign government has an incentive to set a MQS on the exports to increase the foreign firm's profits no matter whether the home government is active or not. If the home government imposes a specific tariff below the prohibitive tariff to accommodate entry, both quality levels of the domestic and foreign goods decrease with the tariff.*

Proposition 4 *If the cost asymmetry parameter λ is small enough, the foreign government can use a MQS to make the home government choose the optimal tariff below the prohibitive tariff to allow trade.*

5.2 The Foreign Government as a First Mover

Now consider the case when the foreign government is able to impose a MQS before the home government chooses a tariff. This case is relevant when the home country finds it easier to impose a restrictive trade policy if it is justified as a retaliation to a foreign policy that hurts domestic firms.

This case can be analyzed by introducing an additional stage to the above game, making it a four-stage game. In the first stage, the foreign government chooses the MQS level for its own firm. In the second stage, the home government chooses a specific tariff level. In the third stage, the home firm chooses its quality level. In the fourth stage, the two firms compete in prices.

Solving the game by backward induction, it is noted that the third and fourth stages of the present game are similar to the second and third stages of the previous game, implying that the results derived earlier can be applied here. In the second-stage, the equilibrium tariff is given by equation (37), and it is assumed that it is below the prohibitive tariff level. In the first stage, by taking into account the effects of the MQS level on the tariff, quality, and prices chosen by the corresponding agents in the subsequent stage, the MQS level is chosen according to the following first-order condition:

$$\frac{\mathrm{d}\pi_f^t}{\mathrm{d}s_f} = \frac{\partial \pi_f^t}{\partial s_f} + \frac{\partial \pi_f^t}{\partial s_h}\left(\frac{\partial R_h(s_f,t)}{\partial s_f} + \frac{\partial R_h(s_f,t)}{\partial t}\frac{\partial t}{\partial \bar{s}_f^t}\right) + \frac{\partial \pi_f^t}{\partial t}\frac{\partial t}{\partial \bar{s}_f^t} = 0. \quad (40)$$

Compared to equation (35), the additional terms in equation (40) are

$$\left(\frac{\partial \pi_f^t}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial t} + \frac{\partial \pi_f^t}{\partial t}\right)\frac{\partial t}{\partial \bar{s}_f^t} > 0,$$

where the sign is due to $\partial t/\partial \bar{s}_f^t < 0$ and based on $c'''(e_i) \geq 0$. What this means is, the foreign government's strategic incentive to use a MQS policy is even larger if it can move ahead of the home government, as a higher MQS will induce the home government to impose a lower tariff. Thus, we have the following proposition:

Proposition 5 *If the cost asymmetry parameter λ is small enough and the marginal cost function is weakly convex, i.e., $c'''(e_i) \geq 0$, the foreign government as a Stackelberg leader will set a higher MQS level to induce the home government to impose a lower tariff than in the case of the simultaneous move of the two governments.*

It is worthwhile to check whether a specific tariff is needed if the foreign government is inactive. The third-stage and second-stage equilibria are given by equations (31) and (33). Substituting $(s_h^t(t), s_f^t(t))$ into the home welfare function, and now it is a function of t only. In the first-stage, the home government chooses a specific tariff t to maximize its home welfare. The first-order condition is

$$\begin{aligned}
\frac{\mathrm{d}W_h^t(t)}{\mathrm{d}t} &= \frac{\partial \pi_h^t}{\partial t} + \frac{\partial \pi_h^t}{\partial s_f}\frac{\partial s_f^t}{\partial t} + \frac{\partial CS^t}{\partial t} + \frac{\partial CS^t}{\partial s_h}\frac{\partial s_h^t}{\partial t} + \frac{\partial CS^t}{\partial s_f}\frac{\partial s_f^t}{\partial t} \\
&\quad + q_f^t + t\left[\frac{\partial q_f^t}{\partial t} + \frac{\partial q_f^t}{\partial s_h}\frac{\partial s_h^t}{\partial t} + \frac{\partial q_f^t}{\partial s_f}\frac{\partial s_f^t}{\partial t}\right] \\
&= \frac{4}{3(e_h - e_f)H}\{(\bar{\theta} - \underline{\theta})[\lambda c''(e_h)c''(e_f)(e_h - e_f) \\
&\quad + (\lambda c''(e_f) - c''(e_h))(G - \lambda c'(e_f))] - \lambda c''(e_h)c''(e_f)t\} \\
&= 0. \qquad (41)
\end{aligned}$$

We can find that

$$t^* = (\bar{\theta} - \underline{\theta})\left[(e_h - e_f) + \frac{(G - \lambda c'(e_f))(\lambda c''(e_f) - c''(e_h))}{\lambda c''(e_h)c''(e_f)}\right]. \qquad (42)$$

The second-order condition $\mathrm{d}^2W_h^t/\mathrm{d}t^2 < 0$ is assumed to be satisfied. Evaluating equation (41) at $t = 0$, we find

$$\frac{\mathrm{d}W_h^t}{\mathrm{d}t}(t=0) = \frac{4(\bar{\theta} - \underline{\theta})\lambda c''(e_f)}{3H}\left[c''(e_h) + \left(1 - \frac{c''(e_h)}{\lambda c''(e_f)}\right)\left(\frac{G - \lambda c'(e_f)}{e_h - e_f}\right)\right].$$

When $c''(e_h) \leq \lambda c''(e_f)$, we can make sure that $\frac{\mathrm{d}W_h^t}{\mathrm{d}t}(t=0) > 0$. When $c''(e_h) > \lambda c''(e_f)$, with the assumption that $c'''(e_i)$ is small enough so that $2\lambda c''(e_f) > c''(e_h) > \lambda c''(e_f)$, we can still make sure that $\frac{\mathrm{d}W_h^t}{\mathrm{d}t}(t=0) > 0$ because

$$\begin{aligned}
& c''(e_h) + \left(1 - \frac{c''(e_h)}{\lambda c''(e_f)}\right)\left(\frac{G - \lambda c'(e_f)}{e_h - e_f}\right) \\
> \; & \frac{c'(e_h) - G}{2(e_h - e_f)} + \frac{c''(e_h)}{2\lambda c''(e_f)}\left(\frac{G - \lambda c'(e_f)}{e_h - e_f}\right) + \left(1 - \frac{c''(e_h)}{\lambda c''(e_f)}\right)\left(\frac{G - \lambda c'(e_f)}{e_h - e_f}\right) \\
= \; & \frac{c'(e_h) - G}{2(e_h - e_f)} + \left(1 - \frac{c''(e_h)}{2\lambda c''(e_f)}\right)\left(\frac{G - \lambda c'(e_f)}{e_h - e_f}\right) \\
> \; & 0,
\end{aligned}$$

where the first inequality comes from the assumption that $H > 0$, i.e., $2\lambda c''(e_h)c''(e_f) > c''(e_h)\frac{\partial G}{\partial e_f} + \lambda c''(e_f)\frac{\partial G}{\partial e_h} = c''(e_h)(\frac{G - \lambda c'(e_f)}{e_h - e_f}) + \lambda c''(e_f)(\frac{c'(e_h) - G}{e_h - e_f})$. Thus, imposing a positive tariff will increase the home welfare. We also have to check whether the optimal tariff is below the prohibitive tariff. Note that there is no MQS now, and the equilibrium quality choices are given by equations (33). The prohibitive tariff is the one to make $G = 2\underline{\theta} - \bar{\theta}$ in equations (33), i.e., the market share of the foreign firm equals to zero. That is, at the prohibitive tariff t_p, the home firm and the foreign firm will choose $\underline{e_h} = c'^{-1}(\frac{\bar{\theta} + \underline{\theta}}{2})$ and $\underline{e_f} = c'^{-1}(\frac{2\underline{\theta} - \bar{\theta}}{\lambda})$, respectively, and $G = [c(\underline{e_h}) - \lambda c(\underline{e_f}) - t_p]/[\underline{e_h} - \underline{e_f}] = 2\underline{\theta} - \bar{\theta}$. Thus, $t_p = c(\underline{e_h}) - \lambda c(\underline{e_f}) - (2\underline{\theta} - \bar{\theta})(\underline{e_h} - \underline{e_f})$.[24] Evaluating equation (41) at $t = t_p$, we find[25]

$$\begin{aligned} \left.\frac{\mathrm{d}W_h^t}{\mathrm{d}t}\right|_{t=t_p} &= \frac{4\lambda c''(\underline{e_h})c''(\underline{e_f})}{3(\underline{e_h} - \underline{e_f})H}\left[(\bar{\theta} - \underline{\theta})(\underline{e_h} - \underline{e_f}) - t_p\right] \\ &= \frac{4\lambda c''(\underline{e_h})c''(\underline{e_f})}{3(\underline{e_h} - \underline{e_f})H}\left[\underline{\theta}(\underline{e_h} - \underline{e_f}) - c(\underline{e_h}) + \lambda c(\underline{e_f})\right] \\ &= \frac{4\lambda c''(\underline{e_h})c''(\underline{e_f})}{3H}\left[\underline{\theta} - \frac{c(\underline{e_h}) - \lambda c(\underline{e_f})}{\underline{e_h} - \underline{e_f}}\right] \\ &> 0. \end{aligned} \tag{43}$$

That is, the optimal positive tariff we derive in equation (42) is always greater than t_p. Thus, when $c'''(e_i) \leq 0$, the home welfare is maximized at the tariff level slightly below the prohibitive tariff. Recall from Lemma 3, the home welfare under autarky is maximized when the domestic quality equals to $s_0 + c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$, i.e., $s_0 + \underline{e_h}$. When t is slightly below t_p, the domestic quality is very close to $s_0 + c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$. Although entry is accommodated, the market share of the foreign firm is very close to zero as if there was no trade at all. In that case, the home welfare is maximized. However, if the tariff is set equal to t_p, entry is deterred and the home firm will produce

[24] In fact, when $t = t_p$, the foreign firm earns zero profits either entering the market or staying out of the market. Thus, the home firm would produce the quality level $s_0 + c'^{-1}(\underline{\theta})$ anyway so that entry is deterred at $t = t_p$. Strictly speaking, when t is very close to but below t_p, e_h is very close to $c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$ and e_f is very close to $c'^{-1}[(2\underline{\theta} - \bar{\theta})/\lambda]$. Although the market share of the foreign firm is almost down to zero, entry is still accommodated. However, when $t = t_p$, the home firm will choose $e_h = c'^{-1}(\underline{\theta})$ and the foreign firm will stay out of the market.

[25] See appendix D for a proof of the sign in the following equation.

$s_0 + c'^{-1}(\underline{\theta})$. The home welfare is reduced Thus, when $c'''(e_i) \leq 0$, the home government is better to set the tariff slightly below the prohibitive level to allow a very small import from the foreign country. With the competition of the foreign firm, the home firm would produce a higher quality than what it would produce under autarky. Thus, consumers benefit and the home welfare is higher with small trade than no trade at all.

Proposition 6 *When the foreign government is inactive, the optimal specific tariff level is very close to but slightly below the prohibitive level* $t_p = c(\underline{e_h}) - \lambda c(\underline{e_f}) - (2\underline{\theta} - \bar{\theta})(\underline{e_h} - \underline{e_f})$, *where* $\underline{e_h} = c'^{-1}[(\bar{\theta} + \underline{\theta})/2]$ *and* $\underline{e_f} = c'^{-1}[(2\underline{\theta} - \bar{\theta})/\lambda]$.

When the foreign government is inactive, the home government is able to set the tariff to affect the quality choice of the foreign firm. The optimal tariff is the one slightly below the prohibitive level to allow a small trade rather than to totally ban the trade. With the competition of the foreign firm, the home firm would produce a higher quality that benefits the home consumers. Although the profits of the home firm are smaller than the monopoly profits, the increase in consumer surplus is greater than the loss in the home firm's profits, so the home welfare is higher with a small trade.

When the foreign government is active to adopt a MQS policy, the foreign government can strategically choose the MQS level in order to affect the tariff and the quality of the home firm chosen by the home government and the home firm. By setting a higher MQS level, the foreign government can induce the home government to impose a lower tariff and thus help its firm gain more market share in the home market. Thus, the MQS policy adopted by the foreign government not only helps the foreign firm behave as a Stackelberg leader to choose the quality level ahead of the home firm, but also serves as an instrument to reduce the tariff imposed on its exports.

6 Concluding Remarks

We examined the use of minimum quality standard (MQS) for an open economy. We showed that in the presence of an international duopoly, there are situations in which the country with an inferior technology in quality improvement can use such a policy in a strategic way to shift part of the profit of the advanced firm toward its own firm, thereby improving its own national welfare. In this sense, MQS is similar to other strategic trade policies such as export subsidies that are well known in the literature.

While export subsidies and many other types of subsidies are prohibited by the World Trade Organization (WTO) to be used to promote trade, it seems that MQS is not covered by the current WTO agreement on subsidies and counterveiling duties because it does not directly involved government revenues. What we can learn from this paper is that there are some non-subsidy policies that can also be used strategically in an international context.

We also argued that the current system of remedies, i.e., countries need to challenge to the WTO's dispute settlement procedure in the presence of a prohibited subsidy, provides a first-mover advantage to the country that imposes a strategic trade policy in the first place.

Appendix A

Totally differentiating equation (35) with respect to t we get

$$\begin{aligned}
\frac{\mathrm{d}^2\pi_f^t}{\mathrm{d}s_f\mathrm{d}t} &= \frac{\partial(\mathrm{d}\pi_f^t/\mathrm{d}s_f)}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial t}+\frac{\partial(d\pi_f^t/ds_f)}{\partial t} \\
&= \left(\frac{\partial^2\pi_f^t}{\partial s_h\partial s_f}+\frac{\partial^2\pi_f^t}{\partial s_h^2}\frac{\partial R_h(s_f,t)}{\partial s_f}+\frac{\partial\pi_f^t}{\partial s_h}\frac{\partial^2 R_h(s_f,t)}{\partial s_h\partial s_f}\right)\frac{\partial R_h(s_f,t)}{\partial t} \\
&\quad +\frac{\partial^2\pi_f^t}{\partial s_f\partial t}+\frac{\partial^2\pi_f^t}{\partial s_h\partial t}\frac{\partial R_h(s_f,t)}{\partial s_f}+\frac{\partial\pi_f^t}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial s_f\partial t} \\
&= \left[\left(\frac{\partial^2\pi_f^t}{\partial s_h\partial s_f}+\frac{\partial^2\pi_f^t}{\partial s_h^2}\frac{\partial R_h(s_f,t)}{\partial s_f}\right)\frac{\partial R_h(s_f,t)}{\partial t}\right] \\
&\quad +\frac{\partial^2\pi_f^t}{\partial s_f\partial t}+\frac{\partial^2\pi_f^t}{\partial s_h\partial t}\frac{\partial R_h(s_f,t)}{\partial s_f}+\frac{\partial\pi_f^t}{\partial s_h}\frac{\mathrm{d}(\partial R_h(s_f,t)/\partial s_f)}{\mathrm{d}t} \qquad (44)
\end{aligned}$$

where $\partial R_h(s_f,t)/\partial t = 1/(e_h-e_f)[(\partial G/\partial e_h)-2c''(e_h)] < 0$ due to the second-order condition. $\partial^2\pi_f^t/\partial s_h\partial s_f = e_{21} > 0$ and

$$\begin{aligned}
\frac{\partial\pi_f^t}{\partial s_h} &= \frac{1}{9}(G-2\underline{\theta}+\bar{\theta})[2c'(e_h)-G-2\underline{\theta}+\bar{\theta}] > 0 \\
\frac{\partial^2\pi_f^t}{\partial s_h^2} &= \frac{1}{9}\frac{\partial G}{\partial e_h}\left[2c'(e_h)-G-2\underline{\theta}+\bar{\theta}\right]+\frac{1}{9}(G-2\underline{\theta}+\bar{\theta})\left[2c''(e_h)-\frac{\partial G}{\partial e_h}\right] > 0.
\end{aligned}$$

In addition,

$$\frac{\partial^2\pi_f^t}{\partial s_f\partial t} = -\frac{2[G-\lambda c'(e_f)]}{9(e_h-e_f)} < 0.$$

and

$$\frac{\partial^2\pi_f^t}{\partial s_h\partial t} = -\frac{2[c'(e_h)-G]}{9(e_h-e_f)} < 0.$$

$$
\begin{aligned}
\frac{\mathrm{d}(\partial R_h(s_f,t)/\partial s_f)}{\mathrm{d}t} &= \frac{\partial^2 R_h(s_f,t)}{\partial s_h \partial s_f}\frac{\partial R_h(s_f,t)}{\partial t} + \frac{\partial^2 R_h(s_f,t)}{\partial s_f \partial t} \\
&= \frac{\partial(-e_{12}/e_{11})}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial t} + \frac{\partial(-e_{12}/e_{11})}{\partial t} \\
&= \frac{(\partial G/\partial e_f)Q - 2c''(e_h)}{(e_h-e_f)^2[2c''(e_h)-(\partial G/\partial e_h)]^2} \\
&= \frac{[3(\partial G/\partial e_f)+2(\partial G/\partial e_h)-4c''(e_h)]c''(e_h)}{(e_h-e_f)^2[2c''(e_h)-(\partial G/\partial e_h))]^3} \\
&\quad + \frac{2c'''(e_h)(e_h-e_f)(\partial G/\partial e_f)}{(e_h-e_f)^2[2c''(e_h)-(\partial G/\partial e_h)]^3}, \qquad (45)
\end{aligned}
$$

where $Q = [3c''(e_h) + 2c'''(e_h)(e_h - e_f)]/[2c''(e_h) - (\partial G/\partial e_h)]$. Assuming that $c'''(e_i)$ is small enough, so we can ignore the term with $c'''(e_h)$ in equation (45). With some mathematical operations and denote $\partial G/\partial e_h$ and $\partial G/\partial e_f$ as x and y, respectively, we can get

$$
\frac{\mathrm{d}^2\pi_f^t}{\mathrm{d}s_f\mathrm{d}t} = \frac{4(\partial G/\partial e_f)c''(e_h)}{9[2c''(e_h)-(\partial G/\partial e_h)]^3}\{2x^2+6xy+3y^2-2c''(e_h)[x+3y+2c''(e_h)]\}.
$$

The sign of $\mathrm{d}^2\pi_f^t/\mathrm{d}s_f\mathrm{d}t$ depends on the whole term of $2x^2 + 6xy + 3y^2 - 2c''(e_h)[x+3y+2c''(e_h)]$. We know that $2c''(e_h) \geq \partial G/\partial e_h + \partial G/\partial e_f = x + y$ from footnote 6, so we can make sure that $\mathrm{d}^2\pi_f^t/\mathrm{d}s_f\mathrm{d}t < 0$ because

$$
\begin{aligned}
& 2x^2 + 6xy + 3y^2 - 2c''(e_h)[x + 3y + 2c''(e_h)] \\
< \; & 2x^2 + 6xy + 3y^2 - (x+y)[x + 3y + 2c''(e_h)] \\
= \; & x(x+y) + xy - 2(x+y)c''(e_h) \\
< \; & 2c''(e_h)x + xy - 2(x+y)c''(e_h) \\
= \; & xy - 2c''(e_h)y \\
= \; & [x - 2c''(e_h)]y \\
< \; & 0.
\end{aligned}
$$

Appendix B

Let $z = 2c''(e_h)(e_h - e_f) + c'(e_h) - (2\bar{\theta} - \underline{\theta})$, and totally differentiating equation (37) with respect to t we get

$$
\begin{aligned}
\frac{\mathrm{d}^2 W_h^t}{\mathrm{d}t^2} &= \frac{\partial(\mathrm{d}W_h^t/\mathrm{d}t)}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial t} + \frac{\partial(\mathrm{d}W_h^t/\mathrm{d}t)}{\partial t} \\
&= \frac{(\bar{\theta}-\underline{\theta})[4c''(e_h)+2c'''(e_h)(e_h-e_f-t)]}{3z}\frac{\partial R_h(s_f,t)}{\partial t} - \frac{2c''(e_h)}{3z}
\end{aligned}
$$

As long as $c'''(e_i)$ is small enough, $\mathrm{d}^2W_h^t/\mathrm{d}t^2 < 0$ because $z > 0$ and $\partial R_h(s_f,t)/\partial t < 0$.

Appendix C

Totally differentiating equation (37) with respect to s_f we get

$$
\begin{aligned}
\frac{\mathrm{d}^2 W_h^t}{\mathrm{d}t\mathrm{d}s_f} &= \frac{\partial(\mathrm{d}W_h^t/\mathrm{d}t)}{\partial s_h}\frac{\partial R_h(s_f,t)}{\partial s_f} + \frac{\partial(\mathrm{d}W_h^t/\mathrm{d}t)}{\partial s_f} \\
&= \frac{(\bar{\theta}-\underline{\theta})}{3}\{[\frac{4c''(e_h)+2c'''(e_h)(e_h-e_f-t)}{z}]\frac{\partial R_h(s_f,t)}{\partial s_f} - \frac{2c''(e_h)}{z}\} \\
&= \frac{(\bar{\theta}-\underline{\theta})}{3z}\left\{2c''(e_h)\left[2\frac{\partial R_h(s_f,t)}{\partial s_f}-1\right] + 2c'''(e_h)(e_h-e_f-t)\frac{\partial R_h(s_f,t)}{\partial s_f}\right\},
\end{aligned}
$$

where $e_h - e_f - t^* = (e_h-e_f)[1-(\bar{\theta}-\underline{\theta})] - \frac{(\bar{\theta}-\underline{\theta})[2c'(e_h)-\bar{\theta}-\underline{\theta}]}{2c''(e_h)} < 0$ as long as $\bar{\theta}-\underline{\theta} \geq 1$. If $c'''(e_i) \geq 0$, $c''(e_h) \geq \frac{c'(e_h)-c'(e_f)}{e_h-e_f} > \frac{c'(e_h)-\lambda c'(e_f)}{e_h-e_f} = \frac{\partial G}{\partial e_h} + \frac{\partial G}{\partial e_f}$, implying that $\frac{\partial R_h(s_f,t)}{\partial s_f} = \left(\frac{\partial G}{\partial e_f}\right) / \left(2c''(e_h) - \frac{\partial G}{\partial e_h}\right) < \left[c''(e_h) - \frac{\partial G}{\partial e_h}\right] / \left[2c''(e_h) - \frac{\partial G}{\partial e_h}\right] < \frac{1}{2}$. Thus, we can be sure that $\mathrm{d}^2W_h^t/\mathrm{d}t\mathrm{d}s_f < 0$ and $\partial t/\partial \bar{s}_f^t < 0$ if $c'''(e_i) \geq 0$.

Appendix D

Suppose that $\lambda = 1$ for the time being. The Taylor series shows that

$$
\begin{aligned}
c(\underline{e_h}) &= c(\underline{e_f}) + c'(\underline{e_f})(\underline{e_h}-\underline{e_f}) + \frac{c''(\underline{e_f})}{2}(\underline{e_h}-\underline{e_f})^2 \\
&\quad + \frac{c'''(\underline{e_f})}{6}(\underline{e_h}-\underline{e_f})^3 + \frac{c''''(\underline{e_f})}{24}(\underline{e_h}-\underline{e_f})^4 + \ldots\ldots \qquad (46)
\end{aligned}
$$

Equation (46) can be rewritten as

$$\begin{aligned}
\frac{c(\underline{e_h}) - c(\underline{e_f})}{\underline{e_h} - \underline{e_f}} &= c'(\underline{e_f}) + \frac{c''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f}) \\
&\quad + \frac{c'''(\underline{e_f})}{6}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{24}(\underline{e_h} - \underline{e_f})^3 + \ldots\ldots \\
&= 2\underline{\theta} - \bar{\theta} + \frac{c''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f}) + \\
&\quad \frac{c'''(\underline{e_f})}{6}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{24}(\underline{e_h} - \underline{e_f})^3 + \ldots.. \qquad (47)
\end{aligned}$$

Applying the Taylor series again, we have

$$\begin{aligned}
c'(\underline{e_h}) - c'(\underline{e_f}) &= c''(\underline{e_f})(\underline{e_h} - \underline{e_f}) + \frac{c'''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{6}(\underline{e_h} - \underline{e_f})^3 + \ldots\ldots \\
&= \frac{3(\bar{\theta} - \underline{\theta})}{2}, \qquad (48)
\end{aligned}$$

because $c'(\underline{e_h}) = (\bar{\theta} + \underline{\theta})/2$ and $c'(\underline{e_f}) = 2\underline{\theta} - \bar{\theta}$. Dividing equation (48) by 2 we get

$$\begin{aligned}
\frac{3(\bar{\theta} - \underline{\theta})}{4} &= \frac{c''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f}) + \frac{c'''(\underline{e_f})}{4}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{12}(\underline{e_h} - \underline{e_f})^3 + \ldots\ldots \\
&> \frac{c''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f}) + \frac{c'''(\underline{e_f})}{6}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{24}(\underline{e_h} - \underline{e_f})^3 + \ldots\ldots
\end{aligned}$$

Thus, from equation (47) we get

$$\begin{aligned}
\frac{c(\underline{e_h}) - c(\underline{e_f})}{\underline{e_h} - \underline{e_f}} &= 2\underline{\theta} - \bar{\theta} + \frac{c''(\underline{e_f})}{2}(\underline{e_h} - \underline{e_f}) \\
&\quad + \frac{c'''(\underline{e_f})}{6}(\underline{e_h} - \underline{e_f})^2 + \frac{c''''(\underline{e_f})}{24}(\underline{e_h} - \underline{e_f})^3 + \ldots.. \\
&< 2\underline{\theta} - \bar{\theta} + \frac{3(\bar{\theta} - \underline{\theta})}{4} \\
&= \frac{5\underline{\theta} - \bar{\theta}}{4} \\
&< \underline{\theta}.
\end{aligned}$$

Since $\lambda > 1$, $\underline{\theta} > \left[c(\underline{e_h}) - c(\underline{e_f})\right] / \left[\underline{e_h} - \underline{e_f}\right] > \left[c(\underline{e_h}) - \lambda c(\underline{e_f})\right] / \left[\underline{e_h} - \underline{e_f}\right]$, and this proves $dW_h^t/dt(t = t_p) > 0$ in equation (43).

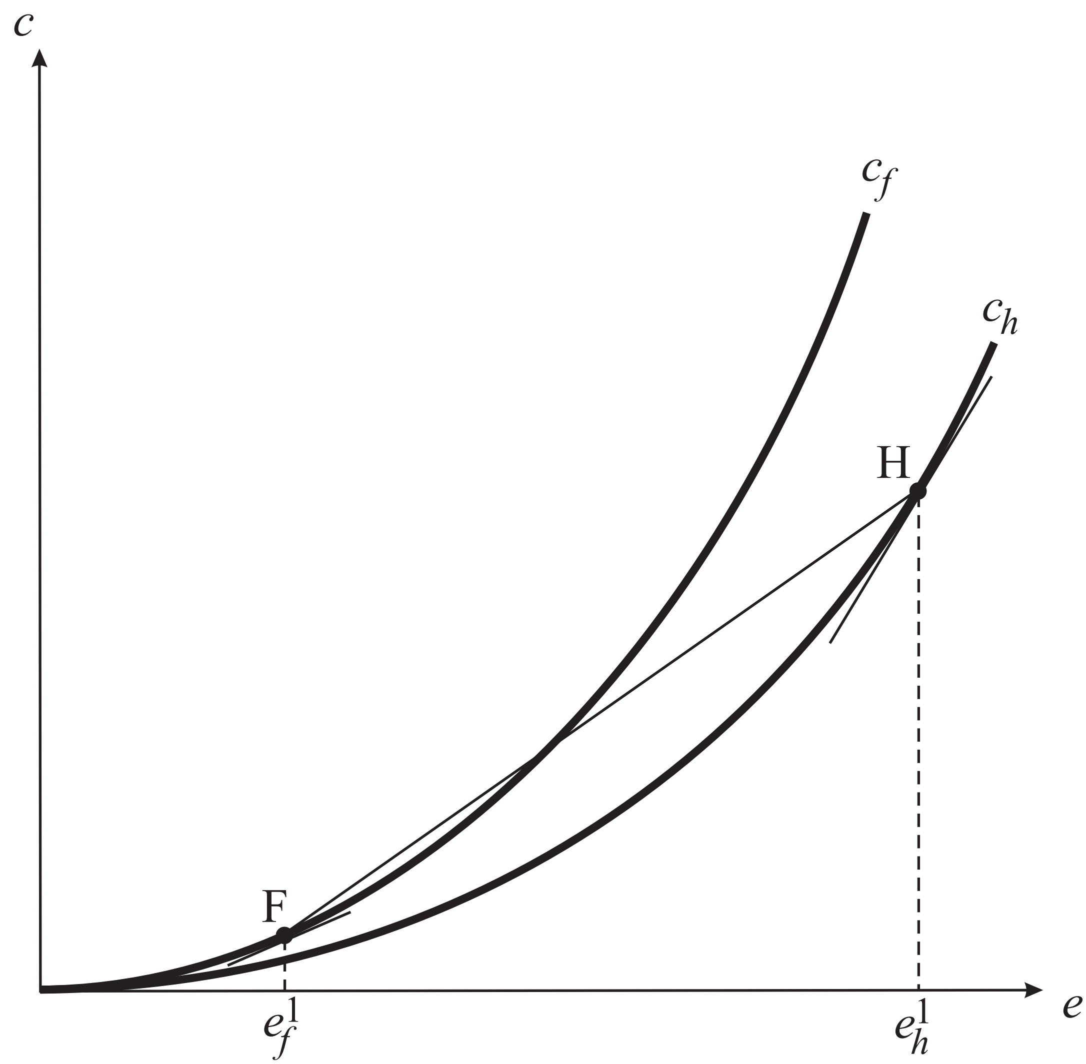

Figure 1

Quality Improvement Functions of the Firms

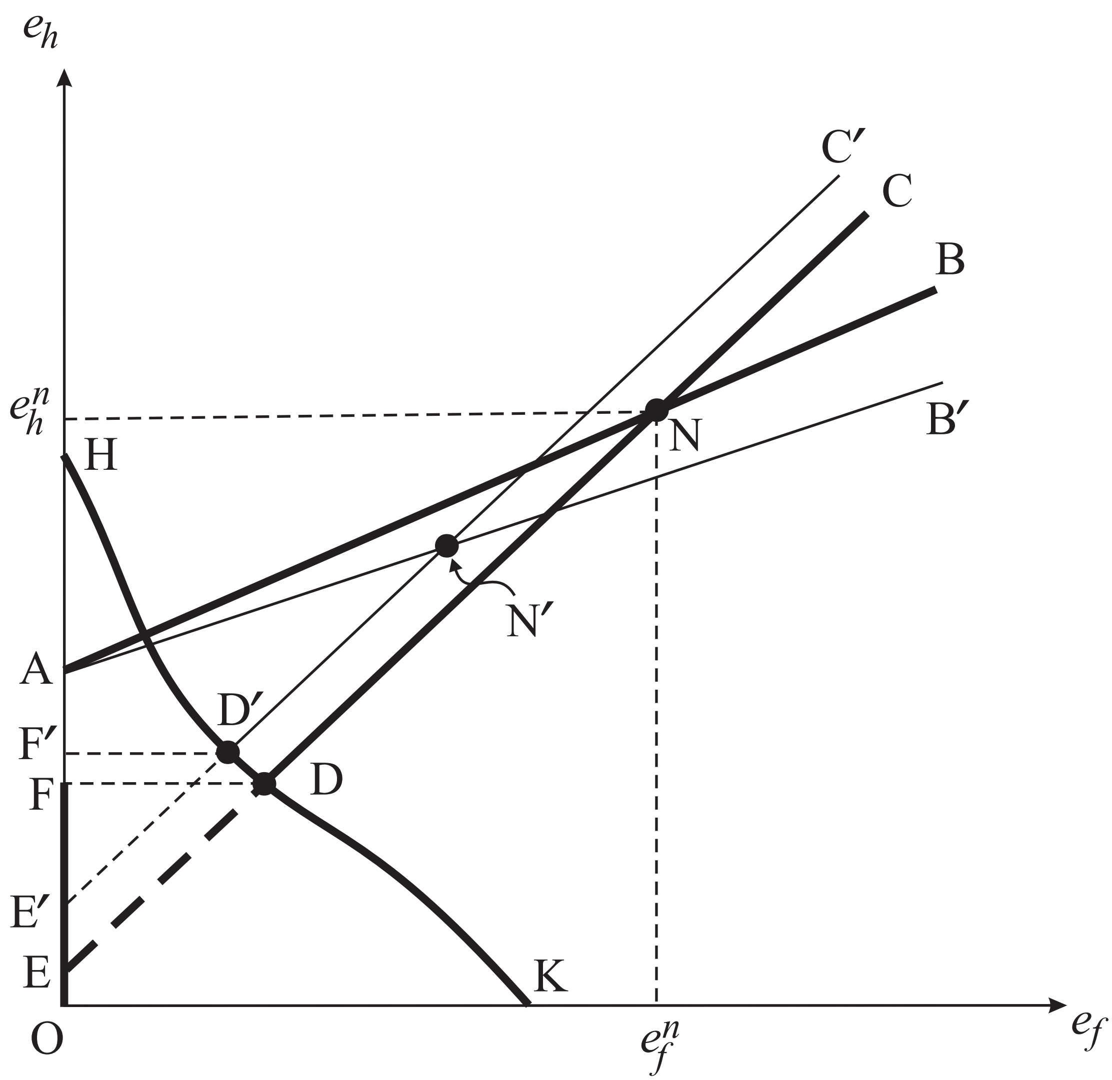

Figure 2

Nash Equilibrium with Quality Competition

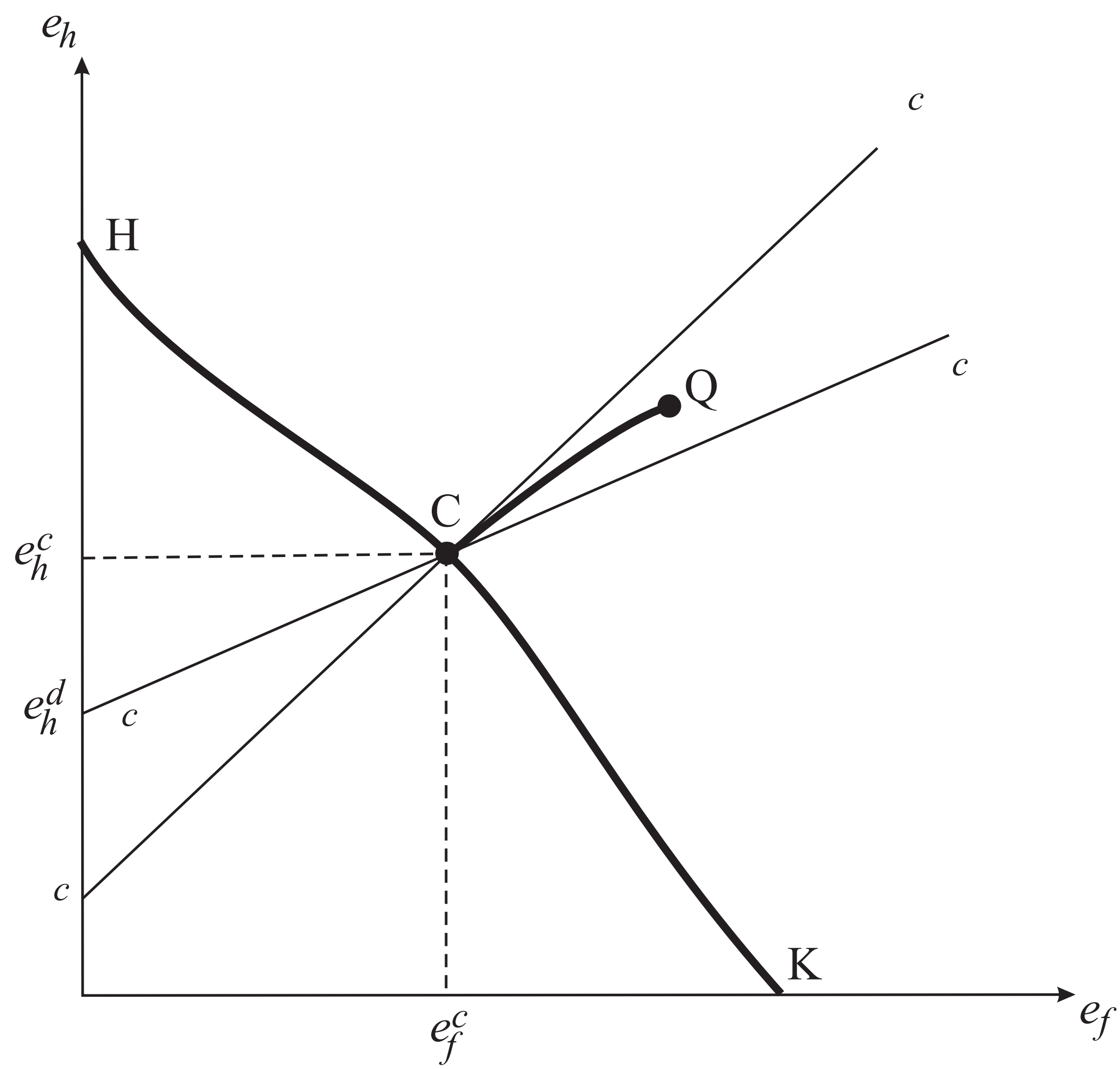

Figure 3

Quality Competition Schedule

References

[1] Boom, A., 1995. Asymmetric international minimum quality standards and vertical differentiation. *Journal of Industrial Economics*, Volume XLIII, 101-119.

[2] Brander J. A., Spencer B. J., 1985. Export subsidies and international market share rivalry. *Journal of International Economics* 18, 83-100.

[3] Crampes, C., Hollander, A., 1995. Duopoly and quality standards. *European Economic Review* 39, 71-82.

[4] Ecchia, G., Lambertini, L., 1997. Minimum quality standards and collusion. *Journal of Industrial Economics*, Volume XLV, 101-113.

[5] Das, S. P., Donnenfeld, S., 1989. Oligopolistic competition and international trade: Quantity and quality restrictions. *Journal of International Economics* 27, 299-318.

[6] Krishna, K., 1987. Tariffs vs. quotas with endogenous quality. *Journal of International Economics* 23, 97-112.

[7] Lutz, S., 2000. Trade effects of minimum quality standards with and without deterred entry. *Journal of Economic Integration* 15 (2), 314-344.

[8] Lutz, S., Lyon, T. P., Maxwell. J. W., 2000. Quality leadership when regulatory standards are forthcoming. *Journal of Industrial Economics*, Volume XLVIII, 331–348.

[9] Ronnen, U., 1991. Minimum quality standards, fixed costs, and competition. *RAND Journal of Economics* 22 (4), 490-504.

[10] Valletti, T. M., 2000. Minimum quality standards under Cournot competition. *Journal of Regulatory Economics* 18 (3), 235-245.

[11] Zigic, K., 1998. Intellectual property rights violations and spillovers in North-South trade. *European Economic Review*, 1779-1799.

[12] Zigic, K., 2000. Strategic trade policy, intellectual property rights protection, and North-South trade. *Journal of Development Economics* 61, 27-60.