International Review of Economics and Finance 20 (2011) 549–561

Contents lists available at ScienceDirect

International Review of Economics and Finance

journal homepage: www.elsevier.com/locate/iref

A welfare analysis of tariffs and equivalent quotas under demand uncertainty: Implications for tariffication

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ARTICLE INFO

Article history:
Received 29 January 2010
Received in revised form 5 October 2010
Accepted 5 October 2010
Available online 12 October 2010

JEL classification:
F1
F12
F13

Keywords:
Tariffs
Equivalent quotas
Market demand uncertainty
Welfare ranking

ABSTRACT

Under market demand uncertainty, we show that quotas can result in a welfare advantage over tariffs for an importing country despite that its government does not capture any quota rents. Specifically, the conditions under which an equivalent quota yields higher expected welfare than a tariff are shown to depend on a set of economic variables. These variables include the initial tariff rate, the relative efficiency in production between home and foreign firms, the probability distribution of random demand shocks that make the quota binding or non-binding under uncertainty, as well as the variance of the stochastic market demand. The analysis of this paper has welfare implications for tariffication.

1. Introduction

Considerable effort has been undertaken by GATT and WTO in recent decades to encourage member countries to reduce or eliminate all sorts of trade barriers. Nevertheless, tariffs and quotas remain to be the two most commonly used policy instruments by trading nations in the world. Voluminous studies have been devoted to evaluating and comparing the efficacy of the two trade policies.

Bhagwati (1965, 1968) shows that a tariff and a quota leading to the same import quantity are fundamentally non-equivalent in the case where a single domestic firm faces competition from supply coming from abroad. The quota, contrary to the tariff, permits the domestic firm to gain some monopoly power. Shibata (1968) extends the analysis and shows that tariffs and quotas are equivalent when the foreign exporter behaves monopolistically, provided that the domestic producer behaves competitively. Later on, contributions by Itoh and Ono (1984), Hwang and Mai (1988), and Fung (1989) analyze the cases of duopoly with a domestic firm competing with a foreign firm in the domestic country's market. The primary conclusion is that tariffs and equivalent quotas have the same effect on domestic price if home and foreign firms engage in Cournot quantity competition. But if the firms engage in Bertrand price competition, tariffs and equivalent quotas are different in terms of their effects on domestic price and profits as shown by Harris (1985) and Krishna (1989). From the perspective of an importing

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doi:10.1016/j.iref.2010.10.002

country's social welfare, Reitzes (1991) shows the welfare advantage of tariffs over quotas in a model of duopoly, where both domestic and foreign firms undertake cost-reducing R&D. Assuming that a government charges quota license fees from foreign firms, Konishi (1999) further finds that quotas can have a welfare advantage over tariffs under oligopoly without entry. But this result is reversed when there is free entry. This strand of the trade literature shows that market structure and competition mode play an important role in determining equivalence/non-equivalence for the domestic price effect and in ranking social welfare between tariffs and quotas.

There is another strand of literature that stresses how market price uncertainty affects the validity of the equivalence between tariffs and quotas. For example, Fishelson and Flatters (1975) compare tariffs and quotas in the classical optimum tariff setting where a country faces a less than perfectly elastic foreign supply curve. They conclude that the tariff-quota equivalence breaks down under a perfectly competitive market.[1] Based on a general equilibrium framework with a perfectly competitive market and uncertain demand, Dasgupta and Stiglitz (1977) show that a tariff is unambiguously superior to a quota, given that the two policies generate the same expected level of government revenue. Young (1980) further shows the conditions under which the superiority of a tariff over a quota could be reversed.

Recently, there are studies that consider elements of information asymmetry or demand uncertainty in influencing an importing country's policy choice between tariffs and quotas under imperfect competition. In particular, the contribution by Matschke (2003) develops a screening model with Cournot competition to show that asymmetric information on market demand between firms and government undermines the equivalence of an optimal tariff and an optimal quota. Instead of focusing on whether tariffs and equivalent quotas have the same effect on domestic price, Chen and Hwang (2006) examine how the policy choice between an optimal tariff and an optimal quota is affected by the levels of demand uncertainty. They find that the optimal trade policy is autarky, a quota (set at the free-trade level), or a tariff, depending on whether the uncertainty levels are high, modest, or low, respectively.

In this paper, we analyze welfare implications of tariffs and equivalent quotas in an import-competing market that involves stochastic demand shocks. We wish to examine whether market price, profit, and social welfare of an importing country are affected differently by the alternative trade policies under market demand uncertainty. Our model is an extension of Hwang and Mai (1988) to allow for the case in which market demand is stochastic. We show that, in the presence of demand uncertainty, a tariff and an equivalent quota have completely different effects on market price, profits, and social welfare despite that domestic and foreign firms engage in Cournot competition. Our paper differs from those of Matschke (2003) and Chen and Hwang (2006) in some important aspects. First, in these two studies policy comparison is based on an optimal tariff and an optimal quota. In our analysis, the comparison between the alternative trade policies is based on *any* relevant tariff rate and an equivalent quota. Practically speaking, tariffs and quotas need not to be set at their socially optimal levels, an approach also adopted in Reitzes (1991) and Konishi (1999). Social-welfare maximization is unquestionably an important objective of an importing country's government, but other factors such as political or non-economical consideration, lobbying activities by interest groups, and potential frictions between trading nations may also affect a country's decisions on the choice of a trade policy. Second, Matschke (2003) examines the scenario where an importing country's government charges quota license fees in order to derive an interior solution for the optimal quota. We assume that the government does not capture any quota rents.[2] Despite the differences in assumptions, our analysis complements the contribution by Matschke (2003). The author stresses information asymmetry in affecting the non-equivalence of an optimal tariff and an optimal quota and shows that government prefers the tariff over the quota. In the present paper, we find that although the absence of quota rents works against a quota policy, an equivalent quota can yield higher expected welfare than a tariff when market demand involves random shocks.

The issue on whether or not tariffs and quotas are equivalent underpins the implication of tariffication in the Uruguay Round Agreement of the WTO. Tariffication refers to the conversion of non-tariff barriers (such as quotas) into tariffs and then gradual reductions in tariffs over time.[3] From the previous contributions as discussed earlier, we know that the bilateral tariff-quota conversions are fundamentally welfare equivalent either in a perfectly competitive market or in an imperfectly competitive market with Cournot firms, provided that quota rents are captured by the domestic government without uncertainty. Kaempfer and Marks (1994) show that welfare effects of tariffication from a quota to a price-equivalent tariff are generally ambiguous. Kaempfer, Ross, and Rutherford (1997) examine the consequences of tariffication when there are domestic market distortions (such as monopoly power and wage rigidities). These two contributions deal with situations under monopoly without taking into account strategic interactions of firms to tariffication under imperfect competition. Focusing on intra-industry trade under monopolistic competition, Jorgensen and Schroder (2007) further show that social welfare increases for a specific tariff but remains the same under an ad valorem tariff if the initial import quota is given by a shared quota (sold quota). Complement to their study, our paper has implications for tariffication in the case of a binding quota under imperfect competition with market demand uncertainty. We find that when the stochastic demand in an import-competing market involves a positive shock, tariffication lowers domestic output, market price, and domestic profit. Given that consumers are better off at the expense

[1] Fishelson and Flatters (1975) interpret the stochastic behavior of market uncertainty as the random disturbances of supply and demand, random measurement error on the various functions in setting the level of tariffs or quotas, or rigidities in the legislative process due to imperfect knowledge about the changes of the economy.

[2] Reitzes (1991) and Chen and Hwang (2006) employ the same assumption that the domestic government does not charge quota license fees.

[3] For extensive discussions on the significance and impact of tariffication see, for example, Cramer, Hansen, and Wailes (1999) and Ingco (1996).

of domestic producers and that the domestic government receives tariff revenues, the welfare effect cannot be determined unambiguously.

The remaining of the paper is organized as follows. In Section 2, we lay out an uncertainty model and determine the equilibrium market price, consumer surplus, profit, and expected welfare for an importing country under a tariff and an equivalent quota. In Section 3, we compare market price and domestic profits for the two alternative trade policies. Section 4 shows the differences in welfare implications of the two policies and derive the conditions under which the quota has a welfare advantage over the tariff. Section 5 contains concluding remarks.

2. The model

We consider a simple framework of an import-competing market in which there are two firms — one domestic and one foreign — producing and selling a homogenous good. [4] Specifically, we assume that market demand for the good in the domestic country is given as:

$$p = a - b(q + q^*) + \theta, \tag{1}$$

where the parameters a and b are all positive, q is the domestic firm's output, q^* is the foreign firm's output, θ is a random variable used to capture stochastic demand shocks with mean $E(\theta) = 0$ and variance $\mathrm{Var}(\theta) = \sigma^2$ as specified in Weitzman (1974), Cooper and Riezman (1989) and Matschke (2003). [5,6] The superscript "*" is used for a variable associated with the foreign firm. This linear demand specification in Eq. (1) is analytically convenient for evaluating alternative trade policies under price uncertainty.

Following Cooper and Riezman (1989), we assume that the domestic government, who commits to regulating foreign imports, determines its policy mode between a tariff and a quota *prior to* the realization of the uncertain market demand. In contrast, the home and foreign firms decide on their profit-maximizing levels of outputs, knowing the scale of the demand shock and hence the actual market demand. In other words, the government has imperfect information about the uncertain demand conditions in implanting either a tariff policy or a quota policy, but the firms know better about the market price information when making their output decisions.

In what follows, we use the framework to solve for the equilibrium outcomes under the tariff and quota regimes (in Sections 2.1 and 2.2), followed by analyses that compare domestic price, profits, and expected welfare between the alternative equilibria (in Sections 3 and 4).

2.1. An import tariff

We first consider the case that the domestic government imposes a specific tariff on foreign imports. Home and foreign firms adopt a Cournot strategy in their output decisions. Based on the stochastic market demand in Eq. (1), profit functions of the home and foreign firms are given, respectively, as

$$\pi = pq - cq = [a - b(q + q^*) + \theta - c]q$$

and

$$\pi^* = pq^* - c^*q^* - tq^* = [a - b(q + q^*) + \theta - c^* - t]q^*,$$

where t denotes tariff imposed on each unit of the imported good, and c and c^* are the (constant) marginal costs of the two firms.

The first-order conditions (FOCs) for the home and foreign firms are:

$$\frac{\partial \pi}{\partial q} = a - 2bq - bq^* + \theta - c = 0 \text{ and } \frac{\partial \pi^*}{\partial q^*} = a - bq - 2bq^* + \theta - c^* - t = 0. \tag{2}$$

These FOCs define the reaction functions of the home and foreign firms. Simultaneously solving the FOCs, we obtain the equilibrium outputs for the firms under the tariff regime as follows:

$$q_t = \frac{1}{3b}(a + \theta - 2c + c^* + t) \tag{3a}$$

[4] The foreign firm serves the market completely through export from a plant in its own country, without setting up another plant in the host country. For the case of a multiplant foreign firm see, e.g., Parai (1999).

[5] The parallel shift of market demand due to shocks is a common approach in the literature. See, e.g., Cooper and Riezman (1989). An alternative approach is to set market price uncertainty as $p = a - [bQ/(1+\theta)]$, where a demand shock will shift the demand curve without changing the price intercept.

[6] Cooper and Riezman (1989) further extends the constrained choice of trade policy as discussed by Brander and Spencer (1985) to allow for quantity controls with demand uncertainty. Following Cooper and Riezman (1989), Arvan (1991) considers the asymmetric timing of policy played between governments and restricts the countries' options to the tax-subsidy policy. Shivakumar (1993) further extends the work of Arvan by allowing governments to choose either a subsidy or quota policy and by considering the timing of implementation. Hwang and Schulman (1993) re-examine the framework of Cooper and Riezman and consider non-intervention as a distinct policy.

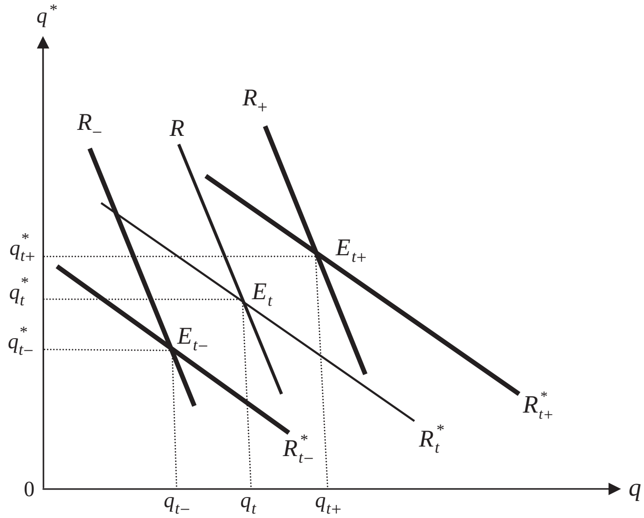

Fig. 1. Equilibrium under tariff with market demand uncertainty.

and

$$q_t^* = \frac{1}{3b}(a + \theta + c - 2c^* - 2t), \tag{3b}$$

where the subscript "t" represents the case of a tariff. We then solve for the market equilibrium output and price[7]:

$$Q_t = \frac{1}{3b}(2a + 2\theta - c - c^* - t); \tag{4}$$

$$p_t = \frac{1}{3}(a + \theta + c + c^* + t). \tag{5}$$

It follows directly from Eqs. (3a), (3b)–(5) that the magnitude of shock to the uncertain market demand, θ, affects each firm's output and the equilibrium market price. These effects can be explained by the reaction curves as illustrated in Fig. 1. Given a tariff rate, let the home and foreign firms' reaction curves without any demand shock ($\theta = 0$) be represented by R and R_t^*, respectively.[8] The Nash equilibrium occurs at point E_t, where the levels of outputs produced by the home and foreign firms are q_t and q_t^*, respectively. For a positive demand shock ($\theta > 0$), the home firm's reaction curve shifts from R to R_+ and the foreign firm's reaction curve shifts from R_t^* to R_{t+}^*, where the subscript "+" denotes a positive shock. The equilibrium changes to E_{t+} at which the levels of outputs produced by the firms increase to q_{t+} and q_{t+}^*. For a negative demand shock ($\theta < 0$), the home and foreign firms' reaction curves shift leftward to R_- and R_{t-}^*, respectively, where the subscript "−" denotes a negative shock. In this case, the equilibrium occurs at E_{t-} and the levels of outputs produced by the firms reduce to q_{t-} and q_{t-}^*. Thus, both firms increase (decrease) their outputs in response to a positive (negative) shock to the uncertain market demand.

Next, using the output equations in Eqs. (3a) and (3b), we derive consumer surplus and profits as follows:

$$CS_t = \frac{b}{2}(Q_t)^2 = \frac{1}{18b}(2a + 2\theta - c - c^* - t)^2; \tag{6}$$

$$\pi_t = \frac{1}{9b}(a + \theta - 2c + c^* + t)^2; \tag{7}$$

$$\pi_t^* = \frac{1}{9b}(a + \theta + c - 2c^* - 2t)^2. \tag{8}$$

[7] Assume that the market size a is large enough to ensure positive outputs for both firms.
[8] Note that the import tariff, t, does not appear in the domestic firm's reaction function. Thus, R is the domestic firm's reaction function under the free trade. However, the import tariff causes the foreign firm's reaction function to shift inward as shown by R_t^*.

Finally, the importing country's expected welfare under uncertainty is defined as the expected value of the sum of domestic profit, consumer surplus, and tariff revenues. That is

$$\begin{aligned} &E(W_t) \\ &= E\left(\pi_t + CS_t + tq_t^*\right) \\ &= E\left\{\frac{1}{18b}\left[2(a+\theta-2c+c^*+t)^2 + (2a+2\theta-c-c^*-t)^2 + 6t(a+\theta+c-2c^*-2t)\right]\right\}. \end{aligned} \tag{9}$$

We will make use of the results in Eqs. (3a), (3b)–(9) when comparing them to those derived under an equivalent quota policy.

2.2. An import quota

We now discuss the case of a quota. Following the tariff-quota equivalence/non-equivalence literature, the quota volume is set at the level identical to the amount of the good imported under the tariff.[9] In the face of uncertain demand situations, equivalent quota (denoted as $\overline{q}^*$) is determined by the expected import volume under the tariff policy.[10] That is, taking the expected value of q_t^* in Eq. (3b) yields

$$\overline{q}^* = E\left(q_t^*\right) = \frac{1}{3b}(a+c-2c^*-2t). \tag{10a}$$

The issue here is that quantity restrictions under the quota policy as specified in Eq. (10a) can be binding or non-binding, depending on whether $\overline{q}^*$ is less or more than the import quantity under free trade.[11] The free-trade level of foreign import (denoted as q_f^*), which is derived by setting $t=0$ in the output Eq. (3b), is:

$$q_f^* = \frac{1}{3b}(a+\theta+c-2c^*). \tag{10b}$$

A comparison of $\overline{q}^*$ and q_f^* in Eqs. (10a) and (10b) reveals two possibilities:

$$\text{(i)The quota } \overline{q}^* \text{ is } \textit{binding} \text{ when } \overline{q}^* < q_f^* \text{ or when } \theta > -2t; \tag{11a}$$

$$\text{(ii)The quota } \overline{q}^* \text{ is } \textit{non-binding} \text{ when } \overline{q}^* > q_f^* \text{ or when } \theta < -2t. \tag{11b}$$

The binding or non-binding quota condition thus depends on the magnitude of a demand shock, θ, and the level of the initial tariff rate, t. Given that θ plays a crucial role in affecting the condition of a binding or non-binding quota, we first discuss the case of a positive shock.

2.2.1. A positive demand shock ($\theta>0$)

It follows from Eq. (11a) that once the stochastic market demand involves a positive shock, the quota set by the domestic government is binding since $\theta>0>-2\,t$. Because the foreign firm is restricted to sell the quota amount, $\overline{q}^*$, the home firm behaves as a Stackelberg leader by determining its output according to the following constrained optimization problem:

$$Max\,\pi = [a-b(q+\overline{q}^*)+\theta]q-cq \text{ subject to } \overline{q}^* = \frac{1}{3b}(a+c-2c^*-2t).$$

The FOC for the home firm is:

$$\frac{\partial\pi}{\partial q} = a-2bq-\frac{1}{3}(a+c-2c^*-2t)+\theta-c = 0. \tag{12}$$

Eq. (12) defines the reaction function of the home firm under the binding quota. Solving the FOC yields the equilibrium domestic output,

$$\hat{q}_+ = \frac{1}{6b}(2a+3\theta-4c+2c^*+2t).$$

[9] See, for example, Itoh and Ono (1984), Hwang and Mai (1988), and Fung (1989).
[10] See Matschke (2003) for a similar setting.
[11] We do not consider issues related to import quality. For studies on tariffs or quotas and their effects on product quality, see, e.g., Krishna (1987) and Beard and Thompson (2003).

We then solve for the equilibrium total consumption ($\hat{Q}_+ = \hat{q}_+ + \overline{q}^*$), price ($\hat{p}_+$), consumer surplus ($\hat{CS}_+$), and domestic and foreign profits ($\hat{\pi}_+$ and $\hat{\pi}^*_+$) under the binding quota with a positive demand shock as follows:

$$\hat{Q}_+ = \hat{q}_+ + \overline{q}^* = \frac{1}{3b}\left(2a + \frac{3}{2}\theta - c - c^* - t\right); \tag{13a}$$

$$\hat{p}_+ = \frac{1}{3}\left(a + \frac{3}{2}\theta + c + c^* + t\right); \tag{13b}$$

$$\hat{CS}_+ = \frac{1}{18b}\left(2a + \frac{3}{2}\theta - c - c^* - t\right)^2; \tag{13c}$$

$$\hat{\pi}_+ = \frac{1}{9b}\left(a + \frac{3}{2}\theta - 2c + c^* + t\right)^2; \tag{13d}$$

$$\hat{\pi}^*_+ = \frac{1}{9b}(a + c - 2c^* - 2t)\left(a + \frac{3}{2}\theta + c - 2c^* - 2t\right). \tag{13e}$$

Next, we examine the quota policy when demand shock to the market is negative.

2.2.2. A negative demand shock that is "mild" ($-2t \leq \theta < 0$)

If the market demand shock is negative, its *level* is critical in affecting the equilibrium. For a small negative shock such that $-2t \leq \theta < 0$, the import quota $\overline{q}^*$ (see Eq. (10a)) remains to be binding. In this case, the equations that characterize the equilibrium under the binding quota with a mild shock are also given by Eqs. (13a)–(13e), except that the value of θ is negative and small.

2.2.3. A negative demand shock that is "wild" ($\theta < -2t < 0$)

For a significantly negative demand shock such that $\theta < -2t < 0$, however, the import quota $\overline{q}^*$ is greater than the free-trade level of foreign output, q^*_f, and hence is non-binding. As a result, the quota equilibrium turns out to be the free-trade equilibrium when there is a significantly negative demand shock. In this case, the optimal foreign output is:[12]

$$\hat{q}^*_- = q^*_{f-} = \frac{1}{3b}(a + \theta + c - 2c^*). \tag{14a}$$

Further, we derive domestic output, total consumption, consumer surplus, and profits under the non-binding quota case as follows:

$$\hat{q}_- = q_{f-} = \frac{1}{3b}(a + \theta - 2c + c^*); \tag{14b}$$

$$\hat{Q}_- = Q_{f-} = \frac{1}{3b}(2a + 2\theta - c - c^*); \tag{14c}$$

$$\hat{CS}_- = \hat{CS}_{f-} = \frac{1}{18b}(2a + 2\theta - c - c^*)^2; \tag{14e}$$

$$\hat{\pi}_- = \hat{\pi}_{f-} = \frac{1}{9b}(a + \theta - 2c + c^*)^2; \tag{14d}$$

$$\hat{\pi}^*_- = \pi^*_{f-} = \frac{1}{9b}(a + \theta + c - 2c^*)^2. \tag{14f}$$

With these equations in mind, we proceed to examine differences in policy implications between a tariff and an equivalent quota.

3. Effects on domestic price, profits, and consumer surplus

In this section, we evaluate and compare equilibrium outcomes between the two alternative trade policies when shocks to the stochastic market demand are positive or negative.

[12] Quota volume set at the free-trade level is equal to foreign output under a tariff regime when $t = 0$ as shown in Section 2.1. In other words, domestic output, market price, total consumption, consumer surplus, domestic profit and social welfare are all the same as those in Eqs. (3a), (3b)–(9) when evaluated at $t = 0$.

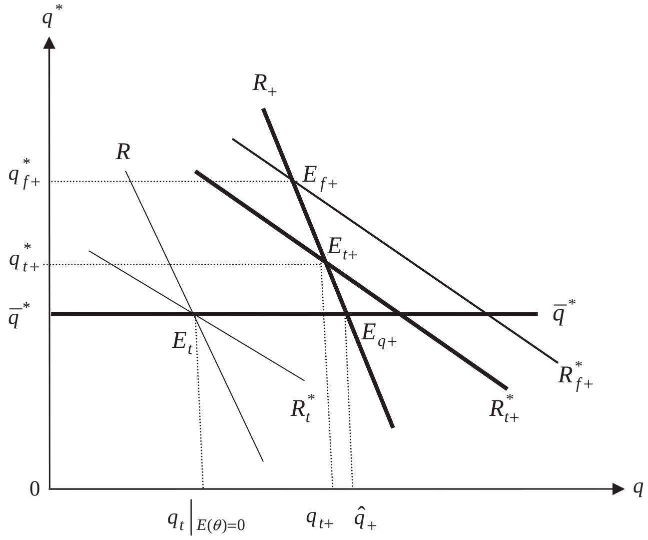

Fig. 2. Tariffs vs. equivalent quotas when the market demand shock is positive.

First, we discuss the case of a positive shock ($\theta>0$) as illustrated by Fig. 2. Under a tariff regime with the expected value of the shock to be zero, the equilibrium occurs at E_t, where the levels of outputs produced by the home and foreign firms are $q_t|_{E(\theta)=0}$ and $\bar{q}^*$, respectively. Note that the output level $\bar{q}^*$ constitutes the upper bound on the amount of the good imported under an equivalent quota. For a positive shock under the tariff regime, the equilibrium occurs at E_{t+}, where the levels of outputs produced by the home and foreign firms are q_{t+} and q^*_{t+}, respectively. For a positive shock under a quota regime, however, foreign output is restrained at q^* as shown by the horizontal line $\bar{q}^*\bar{q}^*$ in Fig. 2. To see whether or not the equivalent quota $\bar{q}^*$ is binding, we draw another set of reaction curves for a positive shock under free trade. As illustrated in Fig. 2, the free-trade equilibrium occurs at a point like E_{f+}, which is the intersection of the home firms' reaction curve R_+ and the foreign firm's reaction curve R^*_{f+}. Since $\bar{q}^*<q^*_{f+}$, the equivalent quota $\bar{q}^*$ is binding when demand shock is positive (see Eq. (11a)). The binding quota equilibrium occurs at point E_{q+}, which is the intersection of the home firm's reaction curve R_+ and the foreign firm's horizontal line $\bar{q}^*\bar{q}^*$. In this case, the equilibrium output produced by the home firm is $\hat{q}_+$.

It comes as no surprise that domestic output is unambiguously greater under the binding quota than that under the tariff. That is, $\hat{q}_+>q_{t+}$. The explanation is straightforward. Due to the binding quota constraint, the foreign firm cannot increase its output at all in response to a positive demand shock. As for the home firm, it is capable of taking advantage of this situation by increasing its output.

What would be the effects of the alternative trade regimes on the domestic market price? To answer this question, we look at p_t in Eq. (5) and $\hat{p}_+$ in Eq. (13b). It follows that with a positive shock, the price is higher under an equivalent quota than under a tariff. Namely, $\hat{p}_+>p_t$. The explanations are as follows. The presence of a positive shock increases market demand such that the home and foreign firms increase their outputs. However, due to the quantity restrictions under the binding quota regime, the foreign firm is unable to expand its output in response to the positive demand shock. Consequently, total consumption is lower under the binding quota than under the tariff. It can easily be verified by comparing Q_t in Eq. (4) to $\hat{Q}_+$ in Eq. (13a). This explains why for a positive demand shock the equilibrium price is relatively higher under the equivalent quota. Our finding stands in contrast with the non-stochastic models of Hwang and Mai (1988) and Fung (1989) that domestic prices for the two trade policies are fundamentally equivalent under Cournot competition.

Next, we discuss the case of a negative demand shock ($\theta<0$). When the shock to the market is negative, the quota constraint $\bar{q}^*$ may be either binding or non-binding depending on the magnitude of the shock. For a negative shock which is 'mild' such that $-2t<\theta<0$, the quota is binding as illustrated in Fig. 3a. Note that the free-trade equilibrium with such a mild negative shock occurs at a point like E_{f-}, which is the intersection of reaction curves R_- and R^*_{f-}. Given that foreign output, set at the free-trade level of q^*_{f-}, is strictly less than the import quota $\bar{q}^*$, this equivalent quota is binding despite that the negative shock is mild. In contrast, for a negative demand shock which is 'wild' such that $\theta<-2t<0$, the quota constraint becomes non-binding because $\bar{q}^*$ is strictly greater than q^*_{f-} (see Eqs. (10a) and (10b)). Fig. 3b illustrates such a case where the quota equilibrium occurs at a point like E_{f-}.

From Fig. 3a and b, we see that the equilibrium level of domestic output is unambiguously lower under the quota regime than under the tariff regime (i.e., $\hat{q}_-<q_{t-}$) when the negative demand shock is either wild or mild. For a negative value of θ, both the home and foreign firms lower their outputs in response to the demand shock under a tariff. Since the foreign firm is not required to pay any tariffs for its export under the quota regime, it produces a greater amount than it would when constrained by the tariff. The equilibrium foreign output is unambiguously higher under the quota than under the tariff, regardless of

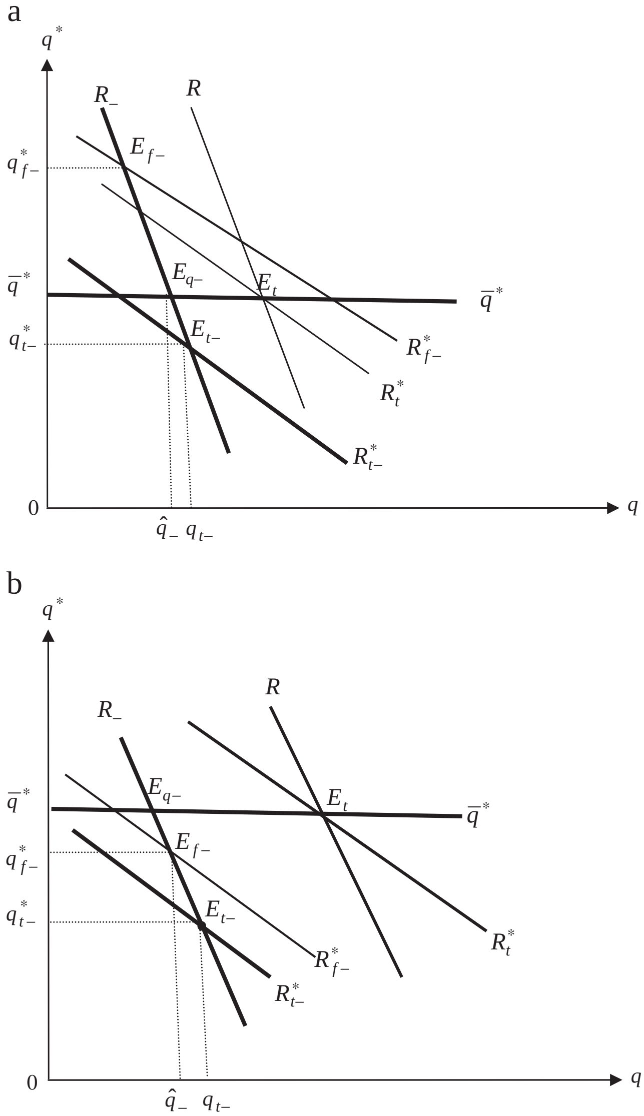

Fig. 3. (a) Tariffs vs. equivalent quotas when the negative demand shock is "mild." (b) Tariffs vs. equivalent quotas when the negative demand shock is "wild."

whether the negative demand shock is mild or wild. This explains why the equilibrium domestic output is relatively lower under the quota policy, i.e., $\hat{q}_{-}<q_{t-}$.

We proceed to analyze the resulting profits for the two alternative trade regimes. For a demand shock which is positive or mild (i.e., $\theta>-2t$) such that the quota is binding, we have from Eqs. (7) and (13d) that the domestic profit differential between the quota and tariff regimes is:

$$\Delta\pi\Big|_{\theta>-2t}=\left(\hat{\pi}-\pi_t\right)\Big|_{\theta>-2t}=\frac{\theta}{36b}[5\theta+4(a-2c+c^*+t)]. \tag{15}$$

Based on Eq. (3a) that $q_t>0$ if and only if $(a-2c+c^*+t)>-\theta$, we have $[5\theta+4(a-2c+c^*+t)]>\theta$. It follows from this inequality and Eq. (15) that

$$(i)\ \text{If}\ \theta>0,\ \text{then}\ \Delta\pi=\frac{\theta}{36b}[5\theta+4(a-2c+c^*+t)]>\frac{\theta^2}{36b}>0. \tag{16a}$$

$$(\text{ii})\ \text{If}\ -2t<\theta<0,\ \text{then}\ \Delta\pi=\frac{\theta}{36b}[5\theta+4(a-2c+c^*+t)]<0<\frac{\theta^2}{36b}. \tag{16b}$$

Eq. (16a) indicates that with a positive demand shock, domestic profit is higher under the quota than under the tariff. Eq. (16b) indicates that for a negative demand shock which is mild, domestic profit is lower under the quota than under the tariff. [13]

But for a demand shock which is wild ($\theta < -2t$) such that the quota is non-binding, we have from Eqs. (7) and (14d) that

$$\Delta\pi\Big|_{\theta<-2t} = (\hat{\pi}-\pi_t)\Big|_{\theta<-2t} = \left[-\frac{2t}{9b}\left(a+\theta-2c+c^*+\frac{t}{2}\right)\right]. \tag{17a}$$

Based on Eq. (14b) that $\hat{q}_-(=q_{f-})>0$ if and only if $(a+\theta-2c+c^*)>0$, we have from this inequality and Eq. (17a) that

$$\Delta\pi\Big|_{\theta<-2t} = (\hat{\pi}-\pi_t)\Big|_{\theta<-2t} < 0. \tag{17b}$$

This result is consistent with the finding in Eq. (16b) for the case of a negative demand shock.

We can also use the last three figures to explain the results mentioned earlier. As discussed in Fig. 2, if there is a positive shock, the equilibrium under a quota occurs at a point like E_{q+} whereas the equilibrium under a tariff occurs at a point like E_{t+}. It is straightforward to show that point E_{q+} lies on a higher iso-profit curve than point E_{t+}. Similarly, for a negative demand shock, point E_{t-} under the tariff lies on an iso-profit curve that yields a higher profit than point E_{q-} under the quota as shown in Fig. 3a and b.

With respect to the consumer surplus differential between the quota and tariff regimes, we have from Eqs. (6) and (13c) that

$$\Delta CS\Big|_{\theta>-2t} = \left(\hat{CS}-CS_t\right)\Big|_{\theta>-2t} = -\frac{\theta}{72b}[7\theta+4(2a-c-c^*-t)]. \tag{18}$$

Based on Eq. (13a) that $\hat{Q}_+>0$ if and only if $(2a-c-c^*-t)>-\frac{3}{2}\theta$, we have $[7\theta+4(2a-c-c^*-t)]>\theta$. It follows from this inequality and Eq. (18) that

$$\text{(i) If } \theta>0, \text{ then } \Delta CS = -\frac{\theta}{72b}[7\theta+4(2a-c-c^*-t)] < -\frac{\theta^2}{72b} < 0; \tag{19a}$$

$$\text{(ii) If } -2t<\theta<0, \text{ then } \Delta CS = -\frac{\theta}{72b}[7\theta+4(2a-c-c^*-t)] > 0 > -\frac{\theta^2}{72b}. \tag{19b}$$

Eqs. (19a) and (19b) indicate that with a positive (negative) demand shock, consumer surplus is lower (higher) under an equivalent quota than under a tariff.

For a demand shock which is wild ($\theta < -2t$) such that the quota is non-binding, we have from Eqs. (6) and (14e) that

$$\Delta CS\Big|_{\theta<-2t} = \left(\hat{CS}-CS_t\right)\Big|_{\theta<-2t} = \frac{t}{9b}\left(2a+2\theta-c-c^*-\frac{t}{2}\right). \tag{20}$$

Based on Eq. (4) that $Q_t>0$ if and only if $(2a+2\theta-c-c^*-t)>0$, we have from this inequality and Eq. (20) that

$$\Delta CS\Big|_{\theta<-2t} = \left(\hat{CS}-CS_t\right)\Big|_{\theta<-2t} > 0. \tag{21}$$

This result is consistent with the finding in Eq. (19b) for the case of a negative demand shock. The analyses mentioned earlier permit us to establish the following proposition:

Proposition 1. When there is a positive (negative) shock to the stochastic demand in an import-competing market, the equilibrium market price and domestic profit are higher (lower) under an equivalent quota than under a tariff. As a consequence of the effect of the positive (negative) shock on prices, domestic consumer surplus is lower (higher) in the equivalent quota case than in the tariff case.

Having discussed differences in profits and consumer surplus between a tariff and an equivalent quota, we move on to analyze their different implications for social welfare.

4. Comparing expected welfare differential between tariffs and quotas

In this section, we compare expected welfare for the two alternative trade policies, noting that the importing country's government does not have perfect information about the uncertain market demand. We discuss two possibilities when an equivalent quota is binding or non-binding.

[13] When the market demand shock is zero as the case discussed by Hwang and Mai (1988), domestic profit remains the same regardless of whether there is a tariff or an equivalent quota.

4.1. An equivalent quota is binding

For a binding quota when $\theta > -2t$, we calculate the expected welfare differential between the quota and tariff regimes as[14]

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta > -2t} = -\frac{t}{3b}(a + c - 2c^* - 2t) + \frac{\sigma^2}{24b}. \tag{22}$$

It follows from Eq. (22) that the variance of the market demand shocks plays an important role in the expected welfare comparison for a binding quota case. If the equivalent quota is binding, domestic expected welfare becomes relatively higher under the quota regime when the variance σ^2 is "significantly large." The reasons are presented as follows. Regardless of the policy mode (a tariff or an equivalent quota), expected profits and consumer surpluses are increasing functions of the variance of demand shocks.[15] For a given magnitude of σ^2, $E(\hat{\pi})$ is greater than $E(\pi_t)$ (by $5\sigma^2/(36b)$) while $E\left(\hat{CS}\right)$ is less than $E(CS_t)$ (by $7\sigma^2/(72b)$). But the expected profit differential, $E(\hat{\pi}) - E(\pi_t)$, is unambiguously greater than the expected consumer surplus differential, $E(\hat{CS}) - E(CS_t)$. Even we exclude the tariff-revenue component, we find that the net effect as measured by $[E(\hat{\pi}) - E(\pi_t)] + [E(\hat{CS}) - E(CS_t)]$ increases with the variance σ^2. Consequently, it follows from Eq. (22) that the expected welfare is relatively higher under an equivalent quota as shown by the following necessary and sufficient condition:

$$E\left(\hat{W}\right)\Big|_{\theta > -2t} > E(W_t)\Big|_{\theta > -2t} \text{ if and only if } \sigma^2 > 8t(a + c - 2c^* - 2t). \tag{23}$$

The finding in Eq. (23) leads to the following proposition:

Proposition 2. In the case of a binding equivalent quota under market demand uncertainty, the quota regime can yield higher expected welfare than the tariff regime when the variance of the demand shocks is sufficiently large.

The economic intuition behind Proposition 2 is straightforward. For a binding quota with a sufficiently large variance of shocks to demand, the quota means that the home firm faces no increase in competition in the face of the increase in demand, and that is why it increases its demand more. If the increase in expected profit outweighs the decrease in expected consumer surplus and the tariff revenues, the expected welfare of the quota turns out to be relatively higher.[16]

4.2. An equivalent quota is non-binding

There is a possibility that an equivalent quota is non-binding when a shock to the market demand is wild ($\theta < -2t < 0$). In this case, the quantity of foreign product set by a quota policy is identical to that under free trade. For such a non-binding quota, we calculate the expected welfare differential between the quota and tariff regimes as[17]

$$E\left(\hat{W}\right)\Big|_{\theta < -2t} - E(W_t)\Big|_{\theta < -2t} = -\frac{t}{6b}(2a - 2c^* - 3t) < 0. \tag{24}$$

Eq. (24) indicates the usual case that the domestic country is better off under the tariff regime than under the quota regime when its government collects tariff revenues.

If we ignore tariff revenues in the expected welfare comparison such that $E(tq_t^*) = 0$, Eq. (24) reduces to

$$E\left(\hat{W}\right)\Big|_{\theta < -2t} - E(W_t)\Big|_{\theta < -2t} = \frac{t}{6b}(2c - 2c^* - t). \tag{25}$$

It follows that if $c^* < (2c - t)/2$, then $E(\hat{W})|_{\theta < -2t} > E(W_t)|_{\theta < -2t}$, which implies that the importing country is able to enjoy the low-cost foreign product. The imposition of an import tariff turns out to lessen such a low-cost benefit. This shows that the domestic expected welfare can be higher under the quota regime than under the tariff regime. If $c^* > c$, a tariff policy works against the high-cost foreign import and is welfare-improving.

The results in Sections 4.1 and 4.2 can also be derived from a more general setting that allows for the possibilities of binding or non-binding equivalent quota according to a probability distribution of random demand shocks (see A-3 in the Appendix).

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[14] See A-1 in the Appendix for a detailed derivation of the result in Eq. (22).

[15] Based on our model, we calculate the following: $E(\pi_t) = [(a - 2c + c^* + t)^2 + \sigma^2]/9b$, $E(CS_t) = [(2a - c - c^* - t)^2 + 4\sigma^2]/18b$, $E(\hat{\pi}) = [(a - 2c + c^* + t)^2 + (9\sigma^2/4)]/9b$, $E(\hat{CS}) = [(2a - c - c^* - t)^2 + (9\sigma^2/4)]/18b$. It is easy to verify that these expected profits and consumer surpluses are increasing functions of σ^2.

[16] It should be noted that this result holds for quasi-linear preferences. The generality of this result requires future research.

[17] See A-2 in the Appendix for a detailed derivation of this result. It should be noted that the expected welfare differential is independent of the variance for quasi-linear preferences when the quota is non-binding. This is due to the fact that a comparison in the expected level of welfare between a tariff and a non-binding quota reduces to one between the tariff regime ($t > 0$) and free trade ($t = 0$). Given that the domestic government makes an *ex ante* decision and that profit and consumer surplus are liner functions of θ, the expected welfare comparison under a non-binding quota has nothing to do with market demand shocks since $E(\theta) = 0$.

5. Concluding remarks

The literature on the comparison of tariffs and quotas has contributed to the understanding of how the two alternative policies affect domestic prices of import-competing goods for different market structures. Nevertheless, it pays relatively little attention to how market demand uncertainty affects social welfare of an importing country under the tariff and quota regimes.

In this paper, we find that equivalent quotas can result in a welfare advantage over tariffs under market demand uncertainty, without assuming that an importing country's government collects any quota rents. The conditions under which social welfare is relatively higher for an equivalent quota are shown to depend on the initial tariff rate, the relative efficiency in production between home and foreign firms, the binding and non-binding conditions of the quota, and the variance of market demand shocks.

It is instructive to note the role of quota rents. For analytical simplicity, we assume away the possibility that an importing country is able to capture quota rents. Apparently, this assumption gives a disadvantage in welfare comparison against a quota policy. If it is relaxed by allowing that some or all of quota rents are retained by the domestic government, our primary finding that equivalent quotas may be preferred to tariffs under market demand uncertainty is strengthened.

The findings of this paper have policy implications for tariffication (which converts a quota into a tariff) when the quota is binding or effective. For an import-competing market that involves a positive shock, tariffication has a negative effect on domestic output, market price, and domestic profit. Consequently, domestic consumers are better off whereas domestic producers are worse off, although the importing country's government is able to collect tariff revenues. Whether tariffication is socially welfare-improving cannot be determined unambiguously, however.

Acknowledgments

We thank Hamid Beladi, the editor, and an anonymous referee for helpful comments and suggestions. We also thank Hong Hwang for valuable comments on an earlier edition of this paper. Hung-Yi Chen would like to acknowledge the financial support from NSC 92-2415-H-031-001.

Appendix A

A-1. Expected welfare differential when the equivalent quota is binding

For the case of a binding quota when the demand shock falls into the range $\theta > -2t$, the difference in the levels of expected welfare between the quota regime and the tariff regime is

$$E\left(\hat{W}\right)\Big|_{\theta>-2t} - E(W_t)\Big|_{\theta>-2t} = E\left(\hat{\pi} + \hat{CS}\right)\Big|_{\theta>-2t} - E\left(\pi_t + CS_t + tq_t^*\right)\Big|_{\theta>-2t} \tag{a.1}$$

where $\hat{\pi}$ and $\hat{CS}$ are respectively given by Eqs. (13d) and (13c), while π_t, CS_t, and q_t^* are respectively given by Eqs. (7), (6), and (3b). Eq. (a.1) can be rewritten as

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta>-2t} = \left[-E\left(tq_t^*\right) + E\left(\hat{\pi} - \pi_t\right) + E\left(\hat{CS} - CS_t\right)\right]\Big|_{\theta>-2t}. \tag{a.2}$$

It follows from Eq. (3b) that

$$E(tq_t^*) = \frac{t}{3b}(a + c - 2c^* - 2t). \tag{a.3}$$

Taking the expected value of the profit differential in Eq. (15) yields

$$\left[E(\hat{\pi} - \pi_t)\right]\Big|_{\theta>-2t} = \frac{5\sigma^2}{36b}, \tag{a.4}$$

Noting that $E(\theta) = 0$ and $\mathrm{Var}(\theta^2) = \sigma^2$. Similarly, taking the expected value of the consumer surplus differential in Eq. (18) yields

$$E\left[\left(\hat{CS} - CS_t\right)\right]\Big|_{\theta>-2t} = -\frac{7\sigma^2}{72b}. \tag{a.5}$$

Substituting Eqs. (a.3)–(a.5) into Eq. (a.2), we have

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta>-2t} = -\frac{t}{3b}(a + c - 2c^* - 2t) + \frac{\sigma^2}{24b}.$$

A-2. Expected welfare differential when the equivalent quota is non-binding

For the case of a binding quota when the demand shock falls into the range $\theta < -2t$, the difference in the levels of expected welfare between the quota regime and the tariff regime is

$$E\left(\hat{W}\right)\Big|_{\theta<-2t} - E(W_t)\Big|_{\theta<-2t} = E\left(\hat{\pi} + \hat{CS}\right)\Big|_{\theta<-2t} - E(\pi_t + CS_t + tq_t^*)\Big|_{\theta<-2t}. \tag{a.6}$$

Rewriting Eq. (a.6) yields

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta<-2t} = \left[-E(tq_t^*) + E\left(\hat{\pi}_f - \pi_t\right) + E\left(CS_f - CS_t\right)\right]\Big|_{\theta<-2t}. \tag{a.7}$$

Note that the first term on the right-hand side of Eq. (a.7) is given by Eq. (a.3). The second can be derived by taking the expected value of the profit differential in Eq. (17a), given that $\hat{\pi} = \pi_f$ when quota is non-binding. That is,

$$\left[E\left(\hat{\pi}_f - \pi_t\right)\right]\Big|_{\theta<-2t} = -\frac{2t}{9b}\left(a - 2c + c^* + \frac{t}{2}\right). \tag{a.8}$$

The third term on the right-hand side of Eq. (a.7) can be derived by taking the expected value of the consumer surplus differential in Eq. (20), given that $\hat{CS} = CS_f$ when quota is non-binding. That is,

$$\left[E\left(CS_f - CS_t\right)\right]\Big|_{\theta<-2t} = \frac{t}{18b}(4a - 2c - 2c^* - t). \tag{a.9}$$

Substituting Eqs. (a.3), (a.7), and (a.8) into Eq. (a.9), we have

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta<-2t} = -\frac{t}{6b}(2a - 2c^* - 3t) < 0.$$

A-3. The more general case

To allow for possibilities of binding or non-binding quotas under uncertainty, we incorporate into the analysis a probability distribution of market demand shocks. The expected welfare comparison between the alternative trade regimes is generally given as

$$\begin{aligned} E\left(\hat{W}\right) - E(W_t) &= Prob.(\theta > -2t)\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta > -2t} + Prob(\theta < -2t)\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{\theta<-2t} \\ &= -E(tq_t^*) + Prob.(\theta > -2t)\frac{\sigma^2}{24b} + Prob(\theta < -2t)\left[\frac{t}{6b}(2c - 2c^* - t)\right]. \end{aligned} \tag{a.10}$$

The probabilities in (a.10) depend on the form of a distribution for market demand shocks. Without the specification of a probability density function, we do not have information about the magnitudes of the probabilities. But based on Eq. (a.10), we find that the higher is the variance σ^2 the larger will be the expected welfare of quotas, other things being equal. For the case in which the initial tariff rate is very small or closed to zero, Eq. (a.10) becomes:

$$\left[E\left(\hat{W}\right) - E(W_t)\right]\Big|_{t\to 0} = Prob.(\theta > -2t)\left(\frac{\sigma^2}{24b}\right) > 0. \tag{a.11}$$

Eq. (a.11) indicates that, if tariff rate is significantly small, an equivalent quota can have a welfare advantage over a tariff as long as the import-competing market involves demand uncertainty.

For the easiness of illustration, we adopt a specific probability density function for market demand shocks. Assume that the random variable θ follows a uniform distribution over the interval $[\underline{\theta}, \overline{\theta}]$, where $\underline{\theta}$ and $\overline{\theta}$ are respectively the lower and upper bounds of the demand shocks. The zero expected value of θ requires that $\underline{\theta} = -\overline{\theta}$, with its variance being equal to $\sigma^2 = (\overline{\theta} - \underline{\theta})^2 / 12$. Base on these conditions, we calculate the upper and lower bounds of θ as follows: $\underline{\theta} = -\sqrt{3}\sigma$ and $\overline{\theta} = \sqrt{3}\sigma$. Therefore, the probabilities of binding and non-binding quotas when market uncertainty possesses a uniform distribution are given, respectively, as $(\sqrt{3}\sigma + 2t)/(2\sqrt{3}\sigma)$ and $(\sqrt{3}\sigma - 2t)/(2\sqrt{3}\sigma)$. The expected welfare differential between the quota and tariff regimes in Eq. (a.10) then becomes

$$E\left(\hat{W}\right) - E(W_t) = -E(tq_t^*) + \frac{1}{48\sqrt{3}b\sigma}\left[\sigma^2\left(\sqrt{3}\sigma + 2t\right) + 4t(2c - 2c^* - t)\left(\sqrt{3}\sigma - 2t\right)\right]. \tag{a.12}$$

We then have the following interesting results. For a tariff rate that approaches zero, Eq. (a.12) reduces to $\mathrm{E}(\hat{W}) - \mathrm{E}(W_t) = \sigma^2 / 48b > 0$. This result implies a relatively higher expected welfare for the case of an equivalent quota. For a non-zero tariff, if the variance σ^2 is small or approaches zero, the expected welfare turns out to be relatively higher under a tariff. But when the variance is "significantly large," it is likely that the expected welfare is relatively higher under an equivalent quota.

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