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Tariff-Rate Quotas, Rent-Shifting and the Selling of Domestic Access

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Tariff-rate quotas (TRQs) have replaced quotas at the end of the Uruguay Round. We analyze TRQs when a foreign firm competes against a domestic firm in the latter's market. Our benchmark is the strategic rent-shifting tariff. We show that the domestic price–equivalent TRQ is a better instrument welfare-wise, as it can extract all of the rents from the foreign firm. We show that different pairs of within-quota tariff and quota can support full rent extraction. The implication is that reduction of the former and enlargement of the latter, holding the above-quota tariff constant, may have no liberalizing effects. The first-best TRQ and the strategic tariff generate different prices. When firms have identical and constant marginal cost, the first-best TRQ entails selling a subsidy to the foreign firm and forcing the exit of the domestic firm.

Introduction

The purpose of this article is to illustrate how the different instruments of tariff-rate quotas (TRQs) can be used strategically to extract rents. This topic is particularly relevant given the ongoing WTO negotiations on market access and the increased concentration in agri-food supply chains. Long regarded as examples of perfectly competitive markets, agricultural markets are increasingly concentrated at the farm input supply, food processing and food retail levels. Even bulk commodities, such as wheat and corn produced by thousands of farmers, are being traded by a few large multinationals and state trading firms that can exercise some degree of market power.

The analysis of trade policy under imperfect competition has shown that governments can extract rents from a foreign monopolist (e.g., Katrak, 1979) or can manipulate rivalries between domestic and foreign firms to increase the profits of the domestic "champions" (Brander and Spencer, 1983). Several papers have identified practical difficulties in implementing strategic policies by pointing out that governments may not always have enough information about the costs of domestic and foreign firms (e.g., Brainard and Martimort, 1997; Creane and Miyagiwa, 2008) or about the nature of the rivalries between firms (e.g., Maggi, 1996). TRQs were introduced in 1994 as instruments to manage market access for sensitive products because the tariffication of non-tariff barriers had prompted some countries to propose tariffs that would have reduced historical levels of market access. TRQs allow countries to tax a certain volume of imports (i.e., the quota) at a within-quota rate and additional imports at a different rate. Little has been written about how they should be set, except in rather specific contexts (e.g., Larue, Gervais and Pouliot, 2007). Table 1 shows some examples of TRQs. The over-quota tariffs that apply to imports in excess of the quota are high (29 percent) or extremely high (887 percent), while the within-quota tariffs range from a low of 5.4 percent to a high of 399 percent. Interestingly, the relative height of the within-quota and above-quota tariffs varies. Gibson et al. (2001) report country averages and find average within-quota and above-quota tariffs of 262 percent and 203 percent, respectively, for Norway, 3 percent and 139 percent for Canada and 10 percent and 52 percent for the United States, which also suggests that there are different patterns in setting TRQs. It is evident that not all countries are willing to give up rents, whether there is scope for strategic policies or not. Our note hopes to fill this gap in the literature by showing that TRQs can be much more potent rent-shifting devices than are tariffs.

Table 1 Examples of TRQs Imposed by Various Countries

Country	TRQ code	Product	Bound within-quota tariff	Bound above-quota tariff
Brazil	Bra001	Apples and pears	13.5	28.8
Canada	Can002b	Poultry	5.4	238
Canada	Can005a	Milk and cream	7.5	241
Korea	Kor024	Manioc	20	887
Korea	Kor031	Citrus fruits	50	144
Norway	Nor024	Milk and cream	399	339
Norway	Nor196	Other vegetables	38	606
Norway	Nor048	Lettuce, cabbage	166	74

The TRQ as a Device to Sell Domestic Market Access

In our benchmark case, the government relies on a specific tariff to affect the behaviour of a domestic firm and a foreign firm (also referred to as firms 1 and 2) which have constant and equal marginal costs (normalized at zero for simplicity). The demand is $p = A - q_1 - q_2$. The firms have Cournot conjectures, and the free trade equilibrium quantities in this case are simply $q_1^{ft} = q_2^{ft} = A/3$. The free trade equilibrium price is $p^{ft} = A/3$, and both firms make the same profit $\pi_1^{ft} = \pi_2^{ft} = A^2/9$. The importing country's welfare is defined as the sum of consumer surplus and firm 1's profit. Given our demand and cost specification, welfare under free trade is $W^{ft} = A^2/3$.

It is well known from the strategic trade policy literature that a tariff can raise the importing country's welfare (Brander, 1995). Ignoring the possibility of retaliation in response to the tariff,[1] the importing country maximizes the same welfare function as above except for the addition of tariff revenue. The imposition of a specific tariff *t* introduces an asymmetry in the profit-maximizing quantities offered by domestic and foreign firms:

$$q_1^*(t) = \frac{A+t}{3}, q_2^*(t) = \frac{A-2t}{3} \quad (1)$$

Because these quantities are strategic substitutes, and given that the stability conditions on the slope of the firms' reaction functions are respected, the domestic (foreign) firm ends up producing more (less) at a higher price than under free trade. Accordingly, the profit of the domestic (foreign) firm is higher (lower) than under free trade for $t > 0$:

$$\pi_1(t) = \frac{(A+t)^2}{9}, \pi_2(t) = \frac{(A-2t)^2}{9} \tag{2}$$

The importing country's welfare boils down to a simple expression quadratic in the tariff: $W(t) = \frac{A^2}{3} + \frac{At}{3} - 0.5t^2$. The maximization of this expression gives us the best rent-shifting tariff: $t^* = A/3$. Replacing t by t^* in $W(t)$, we can show that this tax on imports raises domestic welfare:

$$W(t^*) = \frac{3.5A^2}{9} > \frac{3A^2}{9} = W^{ft} \tag{3}$$

Even though consumer surplus falls, welfare increases relative to free trade because of the increase in the profit of the domestic firm from $9A^2/81$ under free trade to $16A^2/81$ under the rent-shifting tariff. However, the rent-shifting is partial as the foreign firm still make a profit in equilibrium: $\pi_2(t^*) = A^2/81$. Thus, a deviation from free trade can be justified in this context,[2] and this is why the strategic tariff is a logical benchmark for our TRQ analysis.

Let us now suppose that a tariff-rate quota is imposed on the foreign firm instead of a specific tariff. The TRQ is parameterized as $\tilde{T} \equiv \{t_w, \overline{q}_2, t_a\}$, with t_w being the within-quota tariff, t_a the above-quota tariff and $\overline{q}_2$ the quota. As long as the foreign firm's exports are within the quota, $q_2 \in (0, \overline{q}_2]$, the only tariff applied is t_w. If exports exceed the quota, $q_2 > \overline{q}_2$, then the tariff t_w is imposed on the first $\overline{q}_2$ units and the tariff t_a is imposed on all additional units exported by firm 2. Let $\tilde{q}_2(\tilde{T})$ be the foreign firm's profit-maximizing output; the firm's profit can be written as:

$$\pi_2(\tilde{T}) = \begin{cases} \left(A - q_1 - \tilde{q}_2(\tilde{T}) - t_w\right)\tilde{q}_2(\tilde{T}), \text{if } \tilde{q}_2(\tilde{T}) < \overline{q}_2 \\ \left(A - q_1 - \overline{q}_2 - t_w\right)\overline{q}_2, \text{if } \tilde{q}_2(\tilde{T}) = \overline{q}_2 \\ \left(A - q_1 - \tilde{q}_2(\tilde{T})\right)\tilde{q}_2(\tilde{T}) - t_w\overline{q}_2 - t_a\left(\tilde{q}_2(\tilde{T}) - \overline{q}_2\right), \text{if } \tilde{q}_2(\tilde{T}) > \overline{q}_2 \end{cases} \tag{4}$$

When $\tilde{q}_2\left(\tilde{T}\right) > \overline{q}_2$, it is convenient to rewrite the profit of the foreign firm as: $\pi_2\left(\tilde{T}\right) = \left(A - q_1 - \tilde{q}_2\left(\tilde{T}\right)\right)\tilde{q}_2\left(\tilde{T}\right) - \left(t_w - t_a\right)\overline{q}_2 - t_a\tilde{q}_2\left(\tilde{T}\right)$.

Lemma 1: *A) If the TRQ is such that the foreign firm's profit-maximizing output level,* $\tilde{q}_2\left(\tilde{T}\right) \in [0, \overline{q}_2)$*, then the TRQ has the same effect as a specific tariff of* t_w*, and thus* $W\left(\tilde{T}\right) = W\left(t_w\right) \le W\left(t^*\right)$*, and the TRQ is weakly inferior. B) When* $\tilde{q}_2\left(\tilde{T}\right) = \overline{q}_2$*, and the foreign firm would like to export more under the within-quota tariff (and thus* $q_2^*\left(t_w\right) > \overline{q}_2 > q_2^*\left(t_a\right)$*), the TRQ is equivalent to a quota and it is inferior to* t^**. C) When* $\tilde{q}_2\left(\tilde{T}\right) > \overline{q}_2$*, the equilibrium is determined by the above-quota tariff and hence* $\tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t_a\right)$.

Proof: When $\tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t_w\right) < \overline{q}_2$, t_w binds and $\pi_2\left(t_w\right) = \pi_2\left(\tilde{T}\right)$, but $\tilde{q}_2\left(\tilde{T}\right) \underset{<}{\overset{>}{=}} q_2^*\left(t^*\right)$ as $t_w \underset{>}{\overset{<}{=}} t^*$. This may occur when both t_w and t_a are high and $t_w < t_a$ or when $t_w - t_a$ is positive, but not large enough to warrant sales at or beyond $\overline{q}_2$. Clearly, $t_w = t^*, \tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t^*\right) < \overline{q}_2$ is the best possible binding within-quota tariff as shown by (3). When $\tilde{q}_2\left(\tilde{T}\right) = \overline{q}_2$, t_w is small compared to (the possibly prohibitive) t_a and $q_2^*\left(t_w\right) > \overline{q}_2 > q_2^*\left(t_a\right) \ge 0$. If $t_w = t^*$, too little imports enter and consumer surplus is too low. If $\overline{q}_2 = q_2^*\left(t^*\right)$ and $t_w < t^*$, too little rent-shifting is done as $\pi_2\left(t_w, \overline{q}_2\right) > \pi_2\left(t^*\right)$. Finally, when $\tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t_a\right) > \overline{q}_2$, the profit of the foreign firm can be written as $\pi_2\left(\tilde{T}\right) = \left(A - q_1 - \tilde{q}_2\left(\tilde{T}\right) - t_a\right)\tilde{q}_2\left(\tilde{T}\right) - \left(t_w - t_a\right)\overline{q}_2$. The last component is an avoidable fixed cost or fixed rent since $t_w \underset{<}{\overset{>}{=}} t_a$. To insure that the foreign firm does not produce less than $\tilde{q}_2\left(\tilde{T}\right)$, given that the domestic firm produces $q_1^*\left(t_a\right)$, it must be that:

$\pi_2\left(\tilde{T}\right) \ge \max_{q_2 \le \overline{q}_2}\left\{\left[P\left(q_1^*\left(t_a\right), q_2\right) - t_w\right]q_2\right\} \equiv \pi_2\left(t_w; \overline{q}; q_1^*\left(t_a\right)\right)$. QED

Case B) is most common for primary and processed agricultural products (Tangerman, 1996). In fact, many TRQ studies assume that competitive foreign firms face a TRQ such that $0 \le t_w < t_a$, with t_a high enough to be prohibitive. The implication is that foreign firms are allowed to earn rents from the policy and therefore the tariff t_q that

solves $q_2^*(t) = \overline{q}_2$ would be a superior instrument welfare-wise to TRQs structured such that $t_w < t_q < t_a$. Above-quota sales by the foreign firm can only be observed if t_a is sufficiently low. As such, $\tilde{q}_2(\tilde{T}) > \overline{q}_2$ can be observed when $t_w \le t_a$ and t_a is low enough to permit $q_2^*(t_w) \ge q_2^*(t_a) > \overline{q}_2$, but this implies giving up rents to the foreign firm. Alternatively, $\tilde{q}_2(\tilde{T}) > \overline{q}_2$ can be consistent with $t_w > t_a$ provided t_a is small enough to support $\pi_2(\tilde{T}) > \pi_2(t_w), \forall q_2^*(t_w) \le \overline{q}_2$, where $\pi_2(t_w)$ is the unconstrained profit of the foreign firm under a tariff t_w, or $\pi_2(\tilde{T}) > \pi_2(t_w, \overline{q}_2), \forall q_2^*(t_w) > \overline{q}_2$, where $\pi_2(t_w, \overline{q}_2)$ is the foreign firm's constrained profit level. Allowing for $t_w > t_a$ creates additional rent-shifting possibilities because in addition to the standard rent-shifting, achieved by setting $t_a = t^*$, market access can be sold through $\{t_w, \overline{q}_2\}$. In what follows, we explore the rent-shifting possibilities and equilibrium implications of setting the within-quota tariff t_w at a higher level than the above-quota tariff t_a and by assuming that the latter is set at t^*. As such, we first present the TRQ as a device to sell domestic market access.

Lemma 2: *To sell market access to the foreign firm with a TRQ such that* $t_w > t_a = t^*$, t_w *and* $\overline{q}_2$ *must be set such that: 1)* $q_2^*(t_a) > \overline{q}_2$*; 2)* $\pi_2(t_a) - \overline{q}_2(t_w - t_a) \ge 0$*; and 3)* $\pi_2(t_w; q_1^*(t_a)) \equiv \max_{q_2 \le \overline{q}_2} \left\{ \left[P(q_1^*(t_a) + q_2) - t_w \right] q_2 \right\} \le \pi_2(t_a) - \overline{q}_2(t_w - t_a)$.

Proof: To extract all of the rent under the TRQ with $\tilde{q}_2(\tilde{T}) = q_2^*(t^*)$, it must be that $\pi_2(\tilde{T}) = 0$, which requires $q_2^*(t_a) > \overline{q}_2$, $\pi_2(t_a) - \overline{q}_2(t_w - t_a) = 0$. The term $\overline{q}_2(t_w - t_a)$ is the price paid by the foreign firm for having market access. Naturally, if the foreign firm is allowed to retain some rents, then $\pi_2(t_a) - \overline{q}_2(t_w - t_a) > 0$. It must also be that, provided firm 1 produces at its Nash equilibrium level of output, firm 2 not be tempted to deviate by producing $q_2 \in (0, \overline{q}_2]$. Its profit from such a deviation must be weakly negative if all rents are to be extracted or else equal to the level of rents it is allowed to retain under the TRQ. This motivates the third condition. **QED**

The lemma indicates that the pair $\{t_w, \overline{q}_2; t_a\}$ set to achieve a given revenue target must be incentive-compatible to force the foreign firm to produce at the desired level of output $\tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t^*\right)$.

Proposition 1: *If* $t_w > t_a = t^* = A/3$ *and the government wishes to extract all of the rents from the foreign firm, then : A) it can use pairs* $\{t_w, \overline{q}_2\}$ *that satisfy:* $t_w \geq 5A/9, \left(t_w - t^*\right)\overline{q}_2 = \pi_2\left(t^*\right) = A^2/81$ *; B) there is a discontinuity in the reaction function of the foreign firm that leads to another equilibrium at* $\left(q_1, q_2\right) = \left(A/2, 0\right)$.

Proof: At $t_a = t^*, \tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t^*\right)$, $\pi_2\left(\tilde{T}\right) = \pi_2\left(t^*\right) - \left(t_w - t^*\right)\overline{q}_2$. Given that $\pi_2\left(\tilde{T}\right) = 0$ if all the rents are to be extracted and the price of access to the domestic market maximized, then $\left(t_w - t^*\right)\overline{q}_2 = \pi_2\left(t^*\right) = A^2/81$. This defines a specific relation for $\{t_w, \overline{q}_2\}$. However, the latter must be incentive-compatible and hence in production the foreign firm must not wish to deviate from $q_2 = q_2^*\left(t_w\right)$. From lemma 2, it follows that $\left\{P\left(q_1^* + q_2\right) - t_w\right\}_{q_2=0} = \left(\frac{5A}{9} - t_w\right) \leq 0$, and hence $t_w \geq 5A/9$. When the latter holds with equality, we have an upper bound for $\overline{q}_2$, and hence $\overline{q}_2 \leq A/18$. Figure 1 illustrates the $\{t_w, \overline{q}_2\}$ pairs that are feasible when $A = 10$. This proves part A). From (1), if the foreign firm produces at $\tilde{q}_2\left(\tilde{T}\right) = q_2^*\left(t^*\right) = A/9$ and the domestic firm at $q_1^*\left(t^*\right) = 4A/9$ then the foreign firm's reaction function $R_2\left(q_1, t^*\right)$ must be equal to the domestic firm's reaction function $R_1\left(q_2\right)$. This is clearly a Nash equilibrium, and it is depicted by point A in figure 2. Because the foreign firm would incur losses if it was to produce $q_2 \in \left(0, q_2^*\left(t^*\right)\right)$, there is a jump in its reaction function, as shown in figure 2. Given that $q_2 = 0$ also generates the maximum attainable profit $\pi_2 = 0$ when the triplet $\{t_w, \overline{q}_2, t_a\}$ is set to extract all of the rents from the foreign firm and that the domestic firm's best response would be the monopoly output $q_1^M = A/2$, it follows that point B in figure 2 is also a Nash equilibrium. **QED**

Corollary 1: *The total rent–extracting TRQ welfare-dominates the domestic price–equivalent strategic tariff.*

The TRQ and tariff induce firms to produce the same levels of output, thus yielding the same domestic price. The TRQ is a better instrument welfare-wise because it allows the government to extract all of the rents from the foreign firm, which it cannot do with the tariff. As a result, the TRQ enables the government to achieve a higher level of welfare than does the strategic tariff. The Nash TRQ equilibrium without foreign sales (point B in figure 2) is not attractive, because it is less competitive. One way to insure that it does not emerge is to set the TRQ in such a way as to let the foreign firm enjoy some rent. The above analysis naturally extends to cases for which the zero foreign rent target is replaced by a small positive amount: $0 < \pi_2\left(\tilde{T}\right) < \pi_2\left(t^*\right)$.

Watery TRQ Liberalization

As argued previously, it is usually assumed that countries using TRQs rely on very high above-quota tariffs, low within-quota tariffs and tight minimum access commitments. Under perfect competition and the small-country assumption, such a policy is obviously less efficient than free trade and also less efficient than a tariff providing the same market access because of the rent captured by foreign firms. Accordingly, one might wonder why countries deliberately choose such a policy. The most common argument is that countries wish to mimic and preserve the quota equilibrium observed before TRQs replaced import quotas. Having much "water" in the above-quota tariff implies that small tariff reductions will not have any impact on the quota-like equilibrium if the quota of the TRQ remains unchanged. The Korean and Canadian above-quota tariff rates shown in table 1 are extremely high, but trade liberalization may still prove effective provided enlargements in the quota are negotiated. In contrast, in our imperfectly competitive setting, the status quo can be preserved even when $\overline{q}_2$ increases.

Corollary 2: *Starting with a high within-quota tariff t_w and a low quota $\overline{q}_2$, reductions in t_w and increases in $\overline{q}_2$, holding t_a constant at t^*, can support the TRQ equilibrium that extracts all the rents from the foreign firm, as long as the changes remain consistent with the incentive-compatibility constraints.*

The above follows directly from proposition 1, as one of the incentive-compatibility constraints can be rearranged as $t_w = t^* + \frac{A^2}{81\overline{q}_2}$. Clearly, a decrease in t_w and an increase in $\overline{q}_2$, such that $\frac{\partial t_w}{\partial \overline{q}_2} = \frac{-A^2}{81\overline{q}_2^{\,2}}$, are consistent with zero foreign rents as long as $t_w \geq 5A/9$. When t_w falls below that threshold, the government cannot get all of the rents from the foreign firm.

The First-Best TRQ

As shown above, the ability to shift all of the rent of the foreign firm improves the welfare of the importing country. However, the TRQ described in proposition 1 does not achieve a first-best solution because it does not incite domestic and foreign firms to produce enough. This is so because we had constrained the above-quota tariff to be equal to the strategic tariff. We will show that welfare can be increased further through the appropriate setting of the above-quota tariff.

Proposition 2: *Starting at the Nash equilibrium involving strictly positive outputs for both firms at* $t_a = t^*$ *so that the pair* $(t_w, \overline{q}_2)$ *is incentive-compatible,*[3] *a reduction in the above-quota tariff* t_a *allows the policy-active country to increase the rent by adjusting* $(t_w, \overline{q}_2)$ *as long as the incentive-compatibility constraints are respected. As a result, consumer surplus increases, the profit of the domestic firm decreases and overall welfare increases. Given that unit costs are identical and normalized at zero, the welfare-maximizing TRQ forces the exit of the domestic firm and entails selling a subsidy to the foreign firm.*

Proof: The reduction in t_a all else equal increases the profit of the foreign firm, which can be shifted by the government by adjusting the pair $(t_w, \overline{q}_2)$ in such a way as to maintain the incentive-compatibility restrictions. Naturally, the profit of the domestic firm falls when t_a is reduced. Given our assumptions regarding demand and the unit costs of firms, the optimal domestic price is zero and the optimal quantity sold to consumers must be A. This requires an import tax/subsidy of $t_a = -A$, which induces the pair of outputs $q_1 = 0, \tilde{q}_2(\tilde{T}) = A$. To extract all the foreign rents, an entry fee of A^2 must be levied because $\pi_2 = \left(p\tilde{q}_2(\tilde{T})\right) - t_w\overline{q}_2 - t_a\left(\tilde{q}_2(\tilde{T}) - \overline{q}_2\right) = 0$ implies $(t_w + A)\overline{q}_2 = A^2$. To insure that there is no solution in the domain $q_2 \in [0, \overline{q}_2]$, given

$q_1 = 0$ requires $\left.\frac{\partial \pi_2}{\partial q_2}\right|_{q_2=0} = (A - t_w) \leq 0 \rightarrow t_w \geq A$. Hence, the first-best solution can be supported by $\{t_w, \overline{q}, t_a\}$ with $t_w \geq A$, $\overline{q} = \frac{A^2}{t_w + A} < \frac{A}{2}$, $t_a = -A$. **QED**

The best TRQ welfare-dominates the best rent-shifting tariff, but it forces the exit of the domestic firm, unlike the best rent-shifting tariff, which increases the profit of the domestic firm at the expense of the foreign firm. As a result, governments would probably try to achieve the first-best solution through different instruments like price controls or a subsidy to domestic production.

Negotiations on a Subset of Instruments

The liberalization of TRQs can be a complex exercise because progress need not be achieved evenly across instruments. Negotiations over a given instrument may prove tedious, but progress on two instruments may prove sufficient to induce liberalisation in the third one given that the instruments are linked. The following proposition derives conditions under which progress on two of the three policy instruments is sufficient to induce changes in the third one.

Proposition 3: Starting at $t_w > t_a = t^*$ and $q_2 > \overline{q}_2$, increases in $\overline{q}_2$ and decreases in t_w large enough to make $\pi_2(t^*) - (t_w - t^*)\overline{q}_2$ negative will induce the rent-shifting government to lower t_a below t^*.

Proof: If $\pi_2(t^*) - (t_w - t_a)\overline{q}_2 < 0$, the price for market access is too high, but if the foreign firm is to sell in excess of $\overline{q}_2$, then it must be that t_a will be reduced to insure that the TRQ is incentive-compatible. **QED**

Conclusion

Tariff-rate quotas (TRQs) have replaced quotas at the end of the Uruguay Round of multilateral negotiations, but little is known about how they should be set. We start our analysis by assuming that a single domestic firm competes at home against a single foreign firm. It is well known that in this setting an import tariff can be used strategically by the home government to shift rent from the foreign firm. We show that the TRQ can be a more potent instrument by extracting all of the rents that a foreign firm derives under the strategic tariff. There are many pairs of within-quota tariffs and quotas that are incentive-compatible and hence capable of supporting the total

rent–extracting TRQ. The implication is that simultaneous reductions in the within-quota tariff and the enlargement of the quota, holding the above-quota tariff constant, need not have any liberalizing effect. The first-best TRQ entails selling a subsidy to the foreign firm and forcing the exit of the domestic firm.

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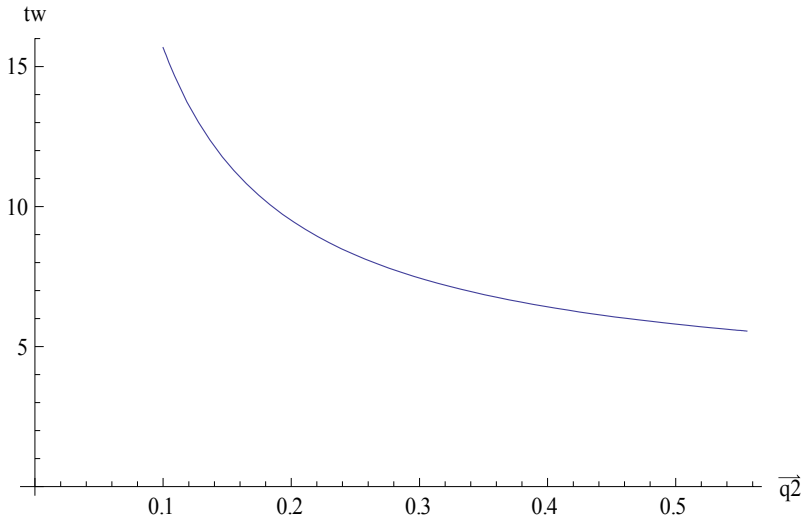

Figure 1 The within-tariff and quota pairs supporting total rent extraction.

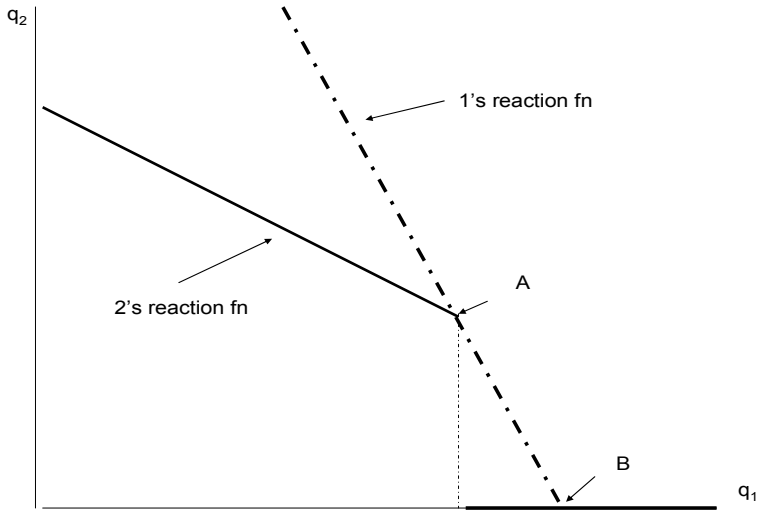

Figure 2 Reaction functions of the TRQ-constrained foreign firm and the unconstrained domestic firm.

Endnotes

1. Retaliation or tariff war has been considered by Johnson (1951), Kennan and Riezman (1988) and Syropoulos (1994), among others.

2. Of course, if one or more of our assumptions do not hold, the policy prescription is likely to change. It is assumed that the government is completely informed about the technologies used by the firms and their behaviour. Maggi (1996) and Creane and Miyagiwa (2008) have relaxed these assumptions.

3. Thus we rule out the other pure-strategy Nash equilibrium $(q_1, q_2) = (A/2, 0)$.