Market Structure and Trade Policy under Asymmetric Information*

By: Mohd Amin

Columbia University

Abstract

Abstract: The paper compares tariffs and import quotas when the home firm has private information about its true cost and the government offers incentive contracts to extract this information. We highlight the role of underlying market structure in determining the ranking of the two policy instruments. Our results show that quotas are at least as efficient as tariffs in implementing the optimal level of protection and strictly more for a wide range of market structures. The exact condition for this is identified. Welfare-based ranking of the two instruments follows from this.

JEL: F13
This draft: December, 2003
Mailing Address: 2400 Virginia Avenue NW,
#C502, Washington, DC 20037.
Email: ma227@columbia.edu

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Introduction

There is a wide body of literature in trade policy which compares tariffs and quotas arguing that the two policy tools may be non-equivalent in equilibrium outcome even when the resulting import-volume is same under them. The present paper attempts to contribute to the rich set of results in this area by highlighting the importance of informational asymmetry and alternative market structures as key factors that determine the stated non-equivalence.

Briefly reviewing the literature, we find a large number of papers have discussed the non-equivalence between tariffs and quotas under different market structures with complete information. The basic conclusion of these papers is that in the quota regime the home-firm rationally believes that the output of the foreign-firm is fixed at the quota limit. That is, its conjecture about the foreign-firm's response to a change in its own output is that of a follower (i.e. equal to zero). If tariff is used instead then the output of the foreign-firm is flexible and the home-firm's conjecture depends on the underlying market structure. Therefore, if the quota is replaced by a tariff such that the two yield the same equilibrium import-volume then the resulting equilibrium will be identical to the one under the quota regime if and only if the home-firm's conjecture in the tariff regime is that of the follower. When this does not hold then tariffs and quotas will yield different equilibrium outcomes even though the resulting import-volume is benchmarked to be same under them (Hwang and Mai, 1988; Itoh and Ono, 1982).

While a number of papers have analyzed informational asymmetry in the context of trade policy, however, most of them are limited to variations of the well-known Brander-Spencer model of optimal export subsidies.[1] In contrast, we consider a simple "home duopoly" model with one home-firm and one foreign-firm selling a homogenous good in home's domestic market. At the beginning of the game, "Nature" assigns a non-negative value to the constant marginal cost of production of the home-firm. This is privately observed by the two firms but not by the (home) government.[2] The restriction to a single home-firm is natural as informational asymmetry is likely to arise with a smaller number of firms. Further, firms are likely to have better information about each other's cost than the government which is our motivation for the asymmetry in information. The next agent to move is the government. Its objective is to maximize pure national welfare. Given the information constraint, it designs a mechanism consisting of a lump-sum transfer to the home-firm and the tariff/quota limit. From the Revelation Principle it follows that the complete information solution can be implemented if and only if an "appropriate" version of the Single Crossing Property (SCP) is satisfied.

Our results show that the optimal quota limit is strictly increasing in the level of home-firm's marginal cost irrespective of the underlying market structure. This ensures that SCP holds so that the complete information optimal quota limit can be implemented. However, when tariffs are used then the situation is qualitatively different. The optimal tariff (under complete information) depends on home-firm's cost through two competing effects. Firstly, a higher cost with the tariff held fixed implies larger import volume which increases the conventional terms-of-trade related gains from protection. This pushes the optimal tariff up-

[1] See, for example, Qiu (1994), Brainard and Martimort (1997).

[2] Similar informational asymmetry is considered in, for example, Brainard and Martimort, 1997. In contrast to this, Qiu, 1994 assumes that the foreign-firm and the home government are both incompletely informed so that his model is a combination of screening and signaling. We use the former structure due to its simplicity.

wards (the *terms-of-trade effect*). Secondly, with a higher cost, the gap between equilibrium local price and home's marginal cost (the mark-up) decreases. Thus, the increase in the output of the home-firm from higher tariff is less valuable to national welfare when evaluated at the margin. This pushes the optimal tariff downwards (the *mark-up effect*). Using the conjectural variations approach to capture alternative market structures, we show that the relative strengths of these two competing forces depends critically on the underlying market structure.[3] The analysis is complete by showing that when the *terms-of-trade effect* is the dominant effect so that the optimal tariff is increasing in home-firm's cost, the appropriate version of SCP is violated leading to a unique equilibrium which is a pooling equilibrium. This contrasts sharply from the equilibrium in the quota regime which is always a separating equilibrium. Our non-equivalence between the two policy tools follows from this.

We contrast here our results with Matschke (2003) which is most closely related to this paper. Matschke considers a Cournot duopoly model when the home-firm has private information about the level of demand in the home market. She finds that tariffs are always (strictly) superior to quotas. That is, while the complete information solution can be implemented in the tariff regime, but this is impossible in the quota regime where the most efficient implementable policy is a uniform quota (*pooling equilibrium*). Our results are completely the opposite of her findings. The intuition for this difference can be briefly described as follows. With the tariff held fixed, a higher demand for the importable implies higher mark-up and import-volume. Thus, the relevant *mark-up effect* and the *terms-of-trade effect* are reinforcing. Consequently, she does not distinguish between these two effects. The

[3] For more details on the use of conjectural variations approach in the context of trade policy, see, for example, Eaton and Grossman (1986). We discuss this issue in more detail in section 3.

optimal tariff is unambiguously increasing in the level of demand which ensures that the appropriate version of SCP is satisfied and the underlying market structure is irrelevant. In fact, Matschke does not consider the role of market structures and restricts her analysis to the Cournot conjectures only.

The structure of the remaining paper is as follows. In section 1 we develop the basic structure of the model and derive the complete information solution. In section 2 we introduce asymmetric information, derive the Spence-Mirrlees sorting condition and the monotonicity condition as they apply to our model. In section 3 we state our main findings. In the conclusion of the paper we briefly review our results and suggest some extensions.

Section 1

1.1 *The basic structure*

We consider a model with two countries called home and foreign. There is one firm in each country. The two firms produce a homogenous good called X which is sold in home's domestic market only. Home's inverse demand function for good X is given by $p = A - X^d$, where $X^d \equiv$ quantity of good X demanded, $p \equiv$ price of good X in home's local market and, A is treated as a parameter of the model.

The structure of the game is as follows. "Nature" moves first at the beginning of the game and assigns a constant marginal cost to the home-firm. Let c denote this cost. The value of c is drawn from a distribution function such that c can take two possible values, c_L,c_H with probabilities θ and $1-\theta$, respectively. We assume that $c_H > c_L \geq 0$. The distribution function is common knowledge to all the players. However, the true value of c (realization of Nature) is observed by the home-firm and the foreign-firm but not by the government. This is a standard assumption in the literature dealing with cost-based informational asymmetry and the motivation for this was discussed in the introduction.[4] The foreign-firm's cost is common knowledge throughout the game and for algebraic simplicity we assume that it is equal to zero.[5]

The next player to move is the government. We assume that it maximizes (pure) national welfare which is equal to the sum of consumer surplus from the consumption of good X in the home country, the tariff/quota revenue and the producer surplus (the profit of the home firm) in the X industry. We assume that all tariff revenue and quota rent is distributed back to home's consumers in a lump-sum fashion. For simplicity, we assume that the ownership of the home-firm is extremely concentrated so that its objective is to maximize its profit in the conventional sense.[6] Given the informational asymmetry, the government offers "incentive contracts" to the home-firm to induce it to reveal its true cost. Equilibrium contracts are determined by the well-known *Revelation* principle which we discuss in detail in section 2. We restrict the government's policy to either tariff or quota but not both. The assumption allows us to contrast the two policy tools easily and is widely used in the literature. The choice of tariff or quota is treated as exogenously given.

Once trade policy is implemented, the two firms compete through quantities. Markets are cleared, utilities of all agents realized and the game ends. We use backward induction

[4] See, for example, Brainard and Martimort, 1997 for a similar assumption.

[5] The exact of value of foreign firm's cost is not important for any of the results in the paper.

[6] With extremely concentrated ownership, the home firm receives an insignificant fraction of tariff revenue and quota rents so that its output decision is independent of tariff revenue/quota rent considerations. Similarly, the owners of the home firm do not consider that a high price for good X will reduce their consumer surplus. The objective of the home firm is then the conventional partial equilibrium profit maximization. See, for example, Grossman and Helpman, 1994, pages 846-847 for more details.

method to solve for the equilibrium.

1.2 *Complete information solution in the tariff regime*

Consider the second stage solution in the tariff regime. For any arbitrarily given non-negative specific tariff rate, t, the home-firm's profit is $\Pi = (A - X - X_f - c)X$ where X (X_f) is the output of the home (foreign) firm. We use the conjectural variations approach to span alternative market structures (degree of competitiveness). This will be explained as we proceed.

The first order condition for profit maximizing output of the home-firm is given by:

$$d\Pi/dX = A - 2X - c - X_f - X\frac{dX_f}{dX} = 0$$

The term dX_f/dX is the *conjecture* that the home-firm holds about the foreign-firm's response to a unit change in its own output, when evaluated at the margin. We will call this the home-firm's conjecture. Let $\lambda \equiv dX_f/dX$. Similarly, the profit of the foreign-firm is given by $(A - X - X_f - t)X_f$ and the first order profit maximization condition is:

$$A - 2X_f - t - X - X_f\frac{dX}{dX_f} = 0$$

Let $\lambda_f \equiv dX/dX_f$ denote the foreign-firm's conjecture about the home-firm's response to a unit change in its own output, when evaluated at the margin. Interpretation of λ_f is similar to the one for λ. As common in the literature, we assume that λ, λ_f are constants.[7] [8]

Solving we get that the equilibrium output of the home-firm is equal to

[7] See, for example, Eaton and Grossman (1986), Hwang and Mai (1988).

[8] The structure can be used to span a wide variety of market structures. For example, the simple Cournot duopoly model is obtained by setting $\lambda = \lambda_f = 0$. The popular home-leadership model, where the home-firm moves first and the foreign-firm is the follower (the leader-follower model), is obtained when $\lambda = -1/2$ and $\lambda_f = 0$.

$$X(\lambda, \lambda_f, c, t) \equiv \frac{(1+\lambda_f)A + t - (2+\lambda_f)c}{(2+\lambda)(2+\lambda_f) - 1}$$

Equilibrium output of the foreign-firm equals

$$X_f(\lambda, \lambda_f, t, c) \equiv \frac{(1+\lambda)A + c - (2+\lambda)t}{(2+\lambda)(2+\lambda_f) - 1}.$$

Equilibrium price p is $p(\lambda, \lambda_f, c, t) = A - X(.) - X_f(.)$. For the remainder of the paper we will use X, X_f, p to denote the equilibrium values as in the previous three expressions.[9]

The government's objective is to maximize national welfare which equals:

$$G^t(c,t) \equiv (X + X_f)^2/2 + tX_f + (A - X - X_f - c)X$$

The first term on the right-hand side (RHS) of the previous expression is the consumer surplus from the consumption of good X, the second is the total tariff revenue of the government and the third term is the profit of the home-firm.[10]

The first order maximization condition for the optimal tariff is given by setting $\partial G^t(c,t)/\partial t = 0$. Doing this we get:

$$X_f(1 - dp/dt) + tdX_f/dt + (p - c)dX/dt = 0 \quad ....(1)$$

The terms on the left-hand side (LHS) of the previous equation capture the change in home's welfare due to a unit increase in its tariff with all changes evaluated at the margin. The first two terms together capture the terms-of-trade related gains to home net of the conventional consumption and production distortion of the tariff. The third term arises due to imperfect competition. That is, under imperfect competition equilibrium price is strictly

[9] Explicit expression for $p(.)$ is stated in Appendix A1.

[10] Explicit expressions for these are stated in Appendix A1(ii).

greater than the marginal cost ($p - c > 0$) implying that production of the importable is less than the socially optimal level. Thus, an increase in home's production of the good due to a higher tariff ($dX/dt > 0$) increases home's welfare as captured by the third term. It is direct to verify that under perfect competition this source of gain is absent since with the initial allocation of resources being optimal, any reallocation of resources across sectors has a *second order effect* only on welfare.[11] As we show later in the paper, the relative strengths of these two sources of gains from protection will be the key factor driving our main results.

Solving the above equation we get that home's optimal tariff equals

$$t(c, \lambda, \lambda_f) \equiv \left[\frac{(1+\lambda_f)(1+\lambda)(3+\lambda)}{\mu_1}\right] A + \left[\frac{\lambda_f - \lambda}{\mu_1}\right] c \quad ....(2)$$

where $\mu_1 \equiv 9 + 10\lambda + 3\lambda^2 + 2\lambda^2\lambda_f + 8\lambda_f(1+\lambda)$

Assumption (A1)

(i) $\lambda > -2/3$ and $\lambda_f > -2/3$

(ii) $A > 2c_H$

Part (i) of the assumption is sufficient to ensure that $\mu_1 > 0$ and that the government's objective function is globally strictly concave in t so that the second order optimization condition is satisfied. Also, part (i) and (ii) together ensure that the optimal tariff is strictly positive, non-prohibitive and the values of all the endogenous variables (at the optimal tariff) are strictly interior.[12]

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[11] This point is well known in the literature. For example, Flam and Helpman (1987, p. 90) note that: "The point is that whenever price exceeds marginal production costs, there is a welfare gain to be made from output expansion. The larger the difference between price and marginal costs, the larger the gain per unit of additional output."

[12] Assumption A1 is not necessary but only sufficient for these interior solutions. For example, an alternative set of assumptions to ensure the same results are that $\lambda > -3/4$, $\lambda_f > -3/4$ and $21c_L > A > 2c_H$. None of our results will be affected if we chose this alternative set of assumptions.

Interpreting equation (2) we note that the optimal tariff can be either increasing or decreasing in c depending on the underlying market structure (values of λ, λ_f). The intuition for this can be easily seen from equation (1). That is, with the tariff held fixed, a higher value of c implies that X_f is higher. Thus, the improvement in home's world price due to a unit increase in its tariff now applies to a larger import-volume base resulting in greater terms-of-trade related benefit (the net value of the first two terms in LHS of equation 1). For brevity call this the *terms-of-trade effect.* This effect pushes the optimal tariff upwards. Next note that a higher value of c implies that $p - c$ is lower so that the third term in LHS of equation 1 is lower. With a lower price-cost mark-up, the benefit to home from a unit increase in its domestic production of the importable resulting from the marginal tariff is now lower. Call this the *mark-up effect.* This effect pushes the optimal tariff downwards as c rises. The net effect of these two competing forces determines whether the optimal tariff is increasing or decreasing in c. To see how this depends on the conjectural values, first hold λ_f constant and note that as λ approaches -1 the home-firm behaves like a perfectly competitive firm so that $p - c$ approaches zero while home's market power, equal to $1 - dp/dt$, approaches 1. It is straightforward to note from this that in this case the *terms-of-trade effect* dominates the *mark-up effect* so that we get a positive relationship between c and the optimal tariff. The reverse happens when λ_f approaches -1. In this case the foreign-firm behaves like a perfectly competitive firm and is willing to supply any amount at its marginal cost. Thus, home faces a perfectly elastic export supply function implying that its tariff has no effect on the world price. Thus the *terms-of-trade effect* is arbitrarily small here and equal to zero in the limit. However, the industry mark-up is strictly positive since this depends on the value of p which is strictly increasing in t and in the limit it rises by one unit as t rises by one unit. Thus, the *mark-up effect* is the dominant effect here implying that we get a negative relationship between t and c. We summarize our results here by noting that the direction of the relationship between the optimal tariff and c depends on the underlying conjectural values. When λ is "sufficiently" close to -1 and λ_f to 1 then the *terms-of-trade effect* is the dominant effect implying that the optimal tariff is increasing in c. The opposite holds when λ is sufficiently close to 1 and λ_f to -1. Our optimal tariff solution simply captures these features.[13]

1.3 *Complete information solution in the quota regime*

To complete the derivation of the complete information solution we now derive the optimal quota limit. In order to do so we first need to specify how quota-rent is distributed between the government and the foreign-firm. The distribution can be quite arbitrary ranging from the government appropriating the entire amount to nothing. The problem is well noted in the literature. To resolve this issue we assume that the quota-rent is distributed in a way such that if a tariff and a quota generate the same volume of imports (under complete information) then the quota rent accruing to the government must equal the tariff revenue. The advantage of using this rule is that it implies that non-equivalence between tariffs and quotas (when the two are set endogenously) cannot arise due to the arbitrariness in the quota-rent rule.[14] Thus, we believe that this rule is the best benchmark case. A problem

[13] We may note here that these effects imply that our results our qualitatively different from the one's in Matschke. That is, Matschke considers asymmetric information with respect to the level of demand in the home country. In this case, the corresponding *terms-of-trade effect* and the *mark-up effect* are both reinforcing and the optimal tariff can never fall when demand rises.

[14] The quota-rent rule specified further implies that if a tariff and quota are set exogenously such that the two yield the same volume of imports then non-equivalence between the two cannot arise due to the quota-rent rule.

may arise here if the quota is not fully utilized by the foreign-firm. However, this possibility is never realized in any of the equilibria discussed in the paper since the quota limit is always binding.[15]

Based on this rule, quota rent accruing to the government equals

$$QR(q,c,\lambda,\lambda_f) \equiv \frac{q(1+\lambda)A + qc - [(2+\lambda)(2+\lambda_f) - 1]q^2}{2+\lambda}$$

The derivation of the optimal quota rule is relatively simple. For any given value of q, the foreign-firm utilizes the quota limit fully[16] and the home-firm chooses its best response output. As in Hwang and Mai, the conjecture of the home-firm is irrelevant in that, with the quota in place, the home-firm rationally believes that the foreign-firm cannot sell more than the quota limit. With the quota fully binding, rationality implies that home's conjecture must be revised to zero. Given the output of the two firms, equilibrium price of good X, consumer surplus, profit levels and quota-rent can be easily computed. The full solution is provided in Appendix (A2).

Computing the government's (national) welfare we have that this equals

$$G^q(c,q) \equiv \frac{(A+q-c)^2}{8} + \frac{(A-q-c)^2}{4} + QR(q,c,\lambda,\lambda_f)$$

The first term in RHS of the previous expression is the consumer surplus from the consumption of good X, the second term is the profit of the home-firm and, the third term is the quota-rent that accrues to the government. Differentiating $G^q(c,q)$ with respect to q we get:

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[15] For a formal proof, see Appendix (A3). Most of the studies dealing with quotas assume that quotas are always fully utilized. See, for example, Hwang and Mai (1988).

[16] See Appendix (A3) for the proof of this.

$$\partial G^q(c,q)/\partial q = \frac{A+q-c}{4} - \frac{A-q-c}{2} + \frac{(1+\lambda)A + c + 2q - (2+\lambda)(2+\lambda_f)q}{2+\lambda} \quad ....(3)$$

Interpretation of the previous equation is simple. Evaluated at the margin and resulting from a unit increase in the quota limit, the first term in RHS is the change in consumer surplus, the second is the change in the profit of the home-firm while the last term is the change in the quota-rent to the government. Equating this RHS to zero and solving for the optimal quota limit we get that this equals

$$q(c,\lambda,\lambda_f) = \left[\frac{2+3\lambda}{\mu_2}\right] A + \left[\frac{6+\lambda}{\mu_2}\right] c \quad .....(4)$$

where $\mu_2 \equiv 18 + 3\lambda + 16\lambda_f + 8\lambda\lambda_f > 0$ under Assumption A1.

It can be easily checked that under Assumption (A1) values of all our endogenous variables are strictly interior at the optimal quota limit, the optimal quota is strictly non-prohibitive and strictly below the free trade volume of imports and, the second order maximization condition for the optimal quota is globally satisfied.[17]

From equation (4) we note that the optimal quota limit is strictly increasing in c for all possible conjectural values. The intuition for this can be noted from equation (3). With the quota limit held constant momentarily, a unit increase in the value of c leads to lower output of the home-firm and lower consumption by home. Thus, the gain in consumer surplus resulting from a unit increase in the quota limit is smaller as the resulting decrease in home's local price applies to a smaller consumption base. This is reflected in the fact that the first term in RHS of equation (3) is decreasing in c. Similarly, this decrease in home's local price applies to a smaller production base of the home-firm leading to a smaller reduction in its

[17] The full solution for the quota regime is stated in Appendix (A2) from which we can see that the solution is interior as stated above.

producer surplus. This is captured by the second term in RHS of equation (3) which is increasing in c. It is direct to verify from equation (3) that the net effect of these opposite effects is that the optimal quota limit is increasing in c. Lastly, the third term in RHS of the equation is increasing in c. That is, the marginal quota rent to the government (with respect to q) is increasing in c. The contrasting behavior of the optimal tariff and quota limit with respect to c will play a key role in later analysis and is summarized in the following Lemma.

Lemma 1: Under complete information the low-cost firm always enjoys higher protection in the quota regime (lower quota limit). This holds in the tariff regime if and only if $\lambda > \lambda_f$. When $\lambda < \lambda_f$ then the optimal tariff is strictly higher (more protective policy) for the high-cost firm.

We now proceed to section 2 where we introduce asymmetric information.

Section 2

In this section we state the SCP, the Monotonocity Condition (MC) and spell out some more structure to establish our final results which is undertaken in section 3.

To this end, let $Y_c^t \equiv$ the amount of transfer from the government to the home-firm in the tariff regime when the home-firm's true cost is equal to c. Similarly, let $Y_c^q \equiv$ the transfer from the government to the home-firm in the quota regime when the home-firm's true cost is c. A negative value of Y_c^t, Y_c^q is interpreted as a transfer from the firm to the government. As common in the literature, we assume that these lump-sum transfers are costless in the sense that a unit of transfer from the government (home-firm) translates into a unit increase in the income of the home-firm (government). Given our simple partial equilibrium framework and the fact that the government maximizes pure national welfare, it follows that such transfers do not affect government's welfare.

For convenience, let $\Pi(t,c) \equiv$ profit of the home-firm when the government implements a tariff at level t and the true cost of the home firm is equal to c. Similarly, let $\Pi(q,c)$ denote the same when the government implements a quota limit of q. Value of $\Pi(t,c)$ is equal to the last term in RHS of $G^t(c,t)$ identity stated in section 1 and $\Pi(c,q)$ is equal to the second term in RHS of $G^q(c,q)$ identity above. Finally, let:

$V(c,t,Y_c^t) \equiv \Pi(t,c) + Y_c^t$ and $W(c,q,Y_c^q) \equiv \Pi(q,c) + Y_c^q$.

The values of $V(.)$ and $W(.)$ are simply the total welfare (earnings) of the home-firm in the tariff and quota regimes, respectively, inclusive of government transfers.

Appropriate version of the Single Crossing Property

A convenient way to express SCP and MC will be to treat c as a continuous variable. This is standard in the literature. Our formal results in section 3 do not use this assumption and hence there is no harm in utilizing it for intuitive understanding here.

Consider any arbitrary tariff policy $t(c)$ and a quota policy $q(c)$. We interpret $t(c)$ as a function which assign a tariff level to each possible value of c. The policy function $q(c)$ can be interpreted similarly. A *necessary* condition for $t(.)$ to be implementable is that the following appropriate version of SCP holds:

$$\frac{\partial}{\partial c}\left(\frac{\partial V/\partial t}{\partial V/\partial Y_c^t}\right)[\partial t(.)/\partial c] \geq 0$$

Similarly, for $q(.)$ to be implementable, a *necessary* condition is that:

$$\frac{\partial}{\partial c}\left(\frac{\partial W/\partial q}{\partial W/\partial Y_c^q}\right)[dq(.)/dc] \geq 0$$

The terms in the square brackets define MC while the remaining (first) term captures the Spence-Mirrlees condition or SCP for the two policy regime. Substitute the optimal tariff function as given by equation (2) in place of $t(.)$ above and similarly set $q(.)$ in the condition above equal to the optimal quota as defined in equation (4). Computing the values of LHS in the previous two inequalities we get the following results:

$$\frac{\partial}{\partial c}\left(\frac{\partial V/\partial t}{\partial V/\partial Y_c^t}\right) = \frac{-2(1+\lambda)(2+\lambda_f)}{((2+\lambda)(2+\lambda_f)-1)^2} < 0 \text{ and } \partial t(.)/\partial c = \frac{\lambda_f - \lambda}{\mu_1}$$

$$\frac{\partial}{\partial c}\left(\frac{\partial W/\partial q}{\partial W/\partial Y_c^q}\right) = 1/2 > 0 \text{ and } \partial q(.)/\partial c = \frac{6+\lambda}{\mu_2} > 0$$

It is clear from the above results that optimal quota rule always satisfies the *necessary* condition for all plausible values of the conjectures. However, in the tariff regime, optimal policy cannot be implemented if $\lambda_f > \lambda$. In fact, a necessary condition for any tariff policy, $t(c)$, to be implementable is that the tariff should be (weakly) decreasing in the value of c. Since the appropriate version of SCP always holds in the quota regime we may conclude that the optimal level of protection can always be implemented using quotas provided that an appropriate sufficiency condition holds too.[18] This is guaranteed in our model since the marginal utility of transfer is finite (equal to 1). However, when the government uses tariffs, there is a wide range of market structures ($\lambda < \lambda_f$) under which optimal policy cannot be implemented since the *necessary* condition mentioned above is violated. Quotas will be strictly superior to tariffs in implementing the optimal level of protection in this scenario. We will take up this analysis more formally with discrete changes in the value of c in section 3. Welfare-based comparison of tariffs and quotas will follow that.

[18] A sufficient condition when the appropriate version of SCP holds is one due to Guesnerie and Laffont (1984). In the context of our model, this requires that the marginal rate of substitution in the $V(.)$ function between tariff and the level of transfers does not increase too fast when the transfer goes to infinity. The same holds for the $W(.)$ function for the quota regime. This condition is automatically satisfied in our model since the marginal utility of transfer to each type of firm is finite and equal to 1. For more details see, for example, Fudenberg and Tirole, 1991, page 261.

Before proceeding to the next section we briefly state the equilibrium conditions when the government implements trade policy without knowing the true cost of the home firm (the *pooling equilibrium*). This will be needed in section 3 to define the participation constraints. For any arbitrarily given value of θ, the government sets tariff/quota at a level in order to maximize its expected payoff which equals $\theta G^J(c_L, J) + (1-\theta)G^J(c_H, J)$, $J \in \{t, q\}$. The function $G^J(.)$ is as defined in section 1. Let $t_\theta \equiv$ as the value of t that maximizes the government's expected welfare in the tariff regime. Similarly, let q_θ denote the optimal quota limit that maximizes the expected welfare of the government. For convenience, let $\tilde{c} \equiv \theta c_L + (1-\theta)c_H$ which is the expected cost of the firm from the government's point of view, given its belief. Computing we get the expressions for t_θ and q_θ as follows:

$$t_\theta = \left[\frac{(1+\lambda_f)(1+\lambda)(3+\lambda)}{\mu_1}\right] A + \left[\frac{\lambda_f - \lambda}{\mu_1}\right] \tilde{c}$$

$$q_\theta = \left[\frac{2+3\lambda}{\mu_2}\right] A + \left[\frac{6+\lambda}{\mu_2}\right] \tilde{c}$$

The interpretation of t_θ and q_θ is same as that of the optimal tariff and quota, respectively, under complete information with the actual cost (c) now replaced by the expected cost, $\tilde{c}$.

With this in place we now proceed to section 3 to derive our main results formally.

Section 3

Tariff regime

Let (t_L, t_H, Y_L^t, Y_H^t) denote a feasible policy function. That is, the government would like to implement a tariff at level t_L and a transfer of amount Y_L^t if the home firm has low cost. If the firm has high cost then the government wants to implement a tariff of t_H and a transfer of amount Y_H^t. We first define the participation constraint of the firm.

The participation constraint defines a reservation utility for each firm-*Type*. As Fudenberg and Tirole (1991) note, this can be quite arbitrary since the government can "coerce" the home-firm to at least any non-negative utility level. As a simple benchmark case we assume that the reservation utility of the home firm is the amount of profit (utility) it can earn by not reporting any cost at all.[19] In this case the government is not sure about the true cost of the firm and hence it maximizes its expected welfare based on its prior belief. Consequently, the government implements t_θ. This implies the following participation constraint in the tariff regime:

$$\Pi(t_i, c_i) + Y_i^t \geq \Pi(t_\theta, c_i) \quad \text{for } i \in \{L, H\}$$

Next we define the incentive compatibility constraints. That is, constraints which ensure that no firm-*Type* has an incentive to misreport its true cost. For the tariff regime, these are given by:

$$\Pi(t_L, c_L) + Y_L^t \geq \Pi(t_H, c_L) + Y_H^t \quad \text{(for the low-cost firm)}$$

$$\Pi(t_H, c_H) + Y_H^t \geq \Pi(t_L, c_H) + Y_L^t \quad \text{(for the high-cost firm)}$$

A policy plan (t_L, t_H, Y_L^t, Y_H^t) is implementable if and only if it satisfies the participation and incentive compatibility constraints. This follows directly from the well-known *Revelation Principle*.

[19] Our results are not affected by the specific value of the reservation utility level. We may note that the participation constraint used in this paper is an *ex-ante* participation constraint which is common in the literature. See, for example, Matschke, 2002.

Proposition 1

In the tariff regime the complete information solution for the optimal tariff (given by equation (2)) is implementable if and only if $\lambda \geq \lambda_f$. When $\lambda < \lambda_f$ then the most efficient implementable policy is a *pooling equilibrium* with $t_L = t_H = t_\theta$.

Proof: See Appendix B1.

Quota regime

Let (q_L, q_H, Y_L^q, Y_H^q) denote a feasible policy in the quota regime. That is, the government would like to implement a quota at level $q_L(q_H)$ and a transfer of amount $Y_L^q(Y_H^q)$ when the home firm has low (high) cost. Since the procedure for establishing the set of implementable policies is similar to the one in the tariff regime we will keep the discussion brief. The participation constraints for the low-cost firm and the high-cost firm are as follows:

$$\Pi(q_i, c_i) + Y_i^q \geq \Pi(q_\theta, c_i) \text{ for } i \in \{L, H\}$$

The incentive compatibility constraints are given by:

$$\Pi(q_L, c_L) + Y_L^q \geq \Pi(q_H, c_L) + Y_H^q \quad \text{(for the low-cost firm)}$$

$$\Pi(q_H, c_H) + Y_H^q \geq \Pi(q_L, c_H) + Y_L^q \quad \text{(for the high-cost firm)}$$

From the *Revelation Principle*, a policy scheme (q_L, q_H, Y_L^q, Y_H^q) is implementable if and only if it satisfies the participation constraints and the incentive compatibility constraints for the quota regime stated above.

Proposition 2

In the quota regime the complete information solution for the optimal quota (given by equation (4)) is implementable for all plausible values of λ, λ_f.

Proof: See Appendix B2.

Ranking of tariffs and quotas: Implementation of optimal policy

From the two *Propositions* above it follows directly that quotas are always at least as efficient as tariffs and strictly better when $\lambda < \lambda_f$ in implementing the optimal level of protection. The intuition for this follows simply from a comparison of the appropriate version of SCP stated in section 2. That is, the low-cost firm benefits more from a unit increase in protection in either regime. The marginal utility of transfer is equal to one and independent of the cost of the firm. Thus, if the high-cost firm is indifferent between two pairs of protection level-transfers then the low-cost type prefers the one with the higher protection level (higher tariff or smaller quota limit). Hence, any policy (tariffs or quotas) to be implementable requires that the government must target a higher level of protection for the low-cost firm (*monotonicity condition*). This necessarily holds in the quota regime for all possible market structures (values of conjectures), however, this may or may not hold in the tariff regime depending on the relative values of the conjectures. Non-equivalence between tariffs and quotas in implementing the optimal level of protection due to informational asymmetry follows from this. Welfare-based ranking of tariffs and quotas is closely related to the results established above and is presented below.

Welfare-based ranking of tariffs and quotas

While the above analysis focused on comparing tariffs and quotas using implementation of the optimal level of protection as the yardstick, we now compare them in national welfare terms. Welfare comparison is slightly complicated because under complete information tariffs and quotas may not be equivalent. However, we find some simple guidelines (conditions) which can simplify the welfare-based comparison. These are as follows.

We first note that contrary to the findings in Hwang and Mai and generally accepted in the literature, our results show that under complete information tariffs and quotas are *not* always non-equivalent outside the Cournot conjectures. It can be easily checked from the solution in the sections above (and in the Appendix) that if $\lambda = 0$ then tariffs and quotas are always equivalent under complete information, irrespective of the value of λ_f. The simple intuition for this is that when $\lambda = 0$ then the home-firm believes that any change in its own output will not affect the output of the foreign-firm in the tariff regime. Now replace the tariff with an equivalent quota in the sense that the two generate the same volume of imports. With the quota in place the home-firm again believes, and rationally so, that the foreign-firm will not change its output simply because the quota limit cannot be exceeded and the foreign firm always finds it profitable to use the quota fully. Since the conjecture of the home-firm is exactly the same in the two situations (regimes), it follows that a substitution of a tariff with an equivalent quota leaves the equilibrium values of all the endogenous variables unchanged. Hwang and Mai fail to notice this because in their mode they assume, at the outset, that the conjectures of the two firms are always equal implying that with $\lambda = 0$, λ_f should be zero too which leads to the Cournot case as the only possibility in their model when the two policy tools are equivalent.[20] The case when $\lambda = 0$ is specially convenient for us since with the complete information solution being identical the only reason for non-equivalence must be the presence of asymmetric information. With this holding, it is straightforward to see that quotas are always strictly welfare-superior to tariffs when $\lambda_f > 0$ and weakly so otherwise.

[20] See, Hwang and Mai (1988), pages 375 and 376.

The reason for this is simple and follows directly from *Proposition* 1 and *Proposition* 2 stated above. With $\lambda = 0$ and $\lambda_f > 0$, optimal level of protection can be implemented in the quota regime but not in the tariff regime. Consequently, the quota regime simply replicates the complete information solution of the tariff regime (and the quota regime since the two are same with $\lambda = 0$). The *pooling equilibrium* outcome obtained in the tariff regime is, by its very definition, strictly inferior to the quota regime outcome where there is a separation of *Types* and the complete information solution is implemented.

Now consider the case when $\lambda > 0$. Under complete information the government implements the optimal tariff. Let the resulting equilibrium volume of imports be denoted by X_f^*. Output of the home-firm then equals $(A - X_f^* - c)/(\lambda + 2)$. Now consider a move to the quota regime. Assume momentarily that the government implements a quota limit at level X_f^*. Output of the home-firm will now equal $(A - X_f^* - c)/2$ which is strictly higher than in the tariff regime (since $\lambda > 0$). Given our quota-rent rule, government's quota rent equals the tariff revenue. However, home-firm's profit is higher in the quota regime because it sells more in the quota regime which implies higher profit given that price is strictly higher than its marginal cost. Similarly, consumer surplus is also higher in the quota regime because, with a larger output of the home-firm, equilibrium price is lower and consumer surplus is higher. Now allow the government to vary the quota limit optimally. This will increase national welfare even more implying that under complete information quotas are strictly superior to tariffs. Now allow for informational asymmetry. From *Proposition* 1 and *Proposition* 2 it follows that the superiority of quotas over tariffs will be further enhanced due to informational problems when $\lambda_f > \lambda$ while it is not undermined when $\lambda_f \leq \lambda$.

Lastly, consider the case when $\lambda < 0$. In this case welfare comparison in more difficult since there are two competing effects. Firstly, under complete information, tariffs and quotas are not equivalent with quotas generally being more anti-competitive and inferior to tariffs in welfare terms. Allowing for informational asymmetry we get the second reason that influences the welfare-based ranking. That is, on pure informational grounds quotas are strictly superior to tariffs in the sense discussed above when $\lambda_f > \lambda$ and weakly so otherwise. The net effect of these two factors on the welfare-based ranking cannot be ascertained without further restrictions on the values of the parameters. Thus, we suggest a cautious approach in the choice of policy regime when $\lambda < 0$. The basic guideline suggested by our results is that when $\lambda < 0$ tariffs are generally superior to quotas under complete information, but the presence of cost-based informational asymmetry biases the case in favor of quotas so that the overall ranking can go either way.

We believe that the model serves to highlight a prescription in favor of quotas over tariffs as far as implementing optimal policy is concerned. Welfare based ranking can be ambiguous in some cases (when $\lambda < 0$). The importance of the underlying market structure is thus important in choosing the better policy tool. Since quotas may be superior to tariffs under incomplete information even though they may be more anti-competitive, our results suggest an important caveat to the proposed benefits from the process of "tarriffication" vigorously followed by GATT, and maintained by WTO now. Before closing this section we would like to mention that while the conjectural variations approach has been criticized in some parts of the literature, however, the criticism does not damage our findings nor does it apply directly to our model. The reason for this is that, as Perry (1982) notes, the weakness of the approach lies in not specifying a sufficient structure to derive the conjectures so that they are internally "consistent". Whatever consistency restriction one may like to impose, the fact remains that once we obtain the values of these "consistent" conjectures then the results of this paper (*Propositions* 1 and 2) can be directly applied.

Conclusion

The paper compares tariffs and quotas in a screening model when the home-firm has private information about its true cost. We argued that in all plausible market structures quotas are weakly superior to tariffs and strictly so under a variety of plausible market structures in implementing the optimal level of protection. Closely related welfare-based ranking of the policy tools was discussed. We suggest some generalizations and extensions below.

We believe that an important extension of the paper will be to include political economy motive for protection. The violation of the appropriate version of SCP in the sense discussed above depends critically on the how the optimal tariff and optimal quota move with the cost reported by the home-firm. In addition to the factors highlighted in this paper, this will depend on the strength of the political economy factors too. Our understanding of how political economy motives affect the ranking of tariffs versus quotas can be further improved by such an exercise.

It will be interesting to explore the non-equivalence issue in alternative frameworks like, for instance, when firms compete in prices with cost-based informational asymmetry. Since the general results with quantity and price competition differ qualitatively the exercise can yield new insights which can complement our findings above.

Lastly, it will be useful to consider other forms of informational asymmetry. For example, when both, the foreign-firm and the home government, are incompletely informed about home firm's true cost then some subtle differences can emerge from the analysis in this paper. The separating equilibrium will implement the optimal level of protection but at the same time it will reveal home firm's true cost to the rival foreign-firm too. The exact impact of this on the non-equivalence between tariffs and quotas is difficult to predict apriori and merits further analysis.

Appendix

Appendix (A1): Complete information solution in the tariff regime

Equilibrium solution for any arbitrarily given values of t, c, λ, λ_f is as follows:

(i) Best response of the home-firm equals $(A - X_f - c)/(\lambda + 2)$ and that of the foreign-firm equals $(A - X - t)/(\lambda_f + 2)$.

(ii) Equilibrium price equals $\dfrac{(1+\lambda)(1+\lambda_f)A + (1+\lambda_f)c + (1+\lambda)t}{(2+\lambda)(2+\lambda_f) - 1}$

(iii) Profit of the home firm equals $\Pi(t, c) = (1+\lambda)\left(\dfrac{(1+\lambda_f)A - (2+\lambda_f)c + t}{(2+\lambda)(2+\lambda_f) - 1}\right)^2$.

(iv) $G^t(c, t) = \left(\dfrac{(2+\lambda+\lambda_f)A - (1+\lambda_f)c - (1+\lambda)t}{((2+\lambda)(2+\lambda_f) - 1)\sqrt{2}}\right)^2 + \dfrac{(1+\lambda)At + ct - (2+\lambda)t^2}{(2+\lambda)(2+\lambda_f) - 1} + \Pi(t, c)$.

The first term on RHS of the previous equation is the consumer surplus from good X, the second is total tariff revenue and the third term is the producer surplus (profit) of the home-firm.

(v) $\partial G^t(c, t)/\partial t = -(1+\lambda)\dfrac{(1+\lambda)(A-t) + (1+\lambda_f)(A-c)}{\{(2+\lambda)(2+\lambda_f) - 1\}^2} + \dfrac{(1+\lambda)A + c - 2(2+\lambda)t}{(2+\lambda)(2+\lambda_f) - 1}$
$+ 2(1+\lambda)\dfrac{(1+\lambda_f)A + t - (2+\lambda_f)c}{\{(2+\lambda)(2+\lambda_f) - 1\}^2}$.

Appendix (A2): Complete information solution in the quota regime

For any value of q, c, λ, λ_f the foreign-firm utilizes the quota limit fully (see Appendix A3) so its output level equals q. The best response output of the home-firm equals $(A - q - c)/2$. Equilibrium price equals $(A - q + c)/2$. Consumer surplus, profit of the home-firm and the government's quota rent are as stated in section 1.

Appendix (A3): Quota limit is always fully utilized

Proof: Suppose the quota limit is set at q^* by the government and the foreign firm utilizes amount $q \leq q^*$. Output of the home firm will then equal $(A - q - c)/2$ which can be seen from Appendix (A2) above. The net profit of the foreign firm equals its total earnings minus the quota rent that it pays to the government. This net profit equals: $(A - q + c)q/2 - QR(q, c, \lambda, \lambda_f)$. Note that the first derivative of this with respect to q is strictly positive under Assumption (A1). This implies that the quota will be fully utilized.

Q.E.D

Appendix (B1): Proof of *Proposition* 1

Proposition 1

In the tariff regime, the complete information solution for the optimal tariff (given by equation (1)) is implementable if and only if $\lambda \geq \lambda_f$. When $\lambda < \lambda_f$ then the most efficient implementable policy is a *pooling* equilibrium with $t_L = t_H = t_\theta$.

Proof: Let IC_L denote the incentive compatibility constraint for the low cost firm and let IC_H denote the same for the high cost firm. Similarly, let $PC_L(PC_H)$ denote the participation constraint for the low (high) cost firm. From section 3 we get: PC_L is equivalent to: $\Pi(t_L, c_L) + Y_L^t \geq \Pi(t_\theta, c_L)$. Similarly, PC_H is equivalent to: $\Pi(t_H, c_H) + Y_H^t \geq \Pi(t_\theta, c_H)$. For the incentive compatibility constraints we have that IC_L is equivalent to $\Pi(t_L, c_L) - \Pi(t_H, c_L) \equiv \Delta_L \geq Y_H^t - Y_L^t$. For the high-cost firm we have that IC_H is equivalent to $\Pi(t_L, c_H) - \Pi(t_H, c_H) \equiv \Delta_H \leq Y_H^t - Y_L^t$. Note the following expressions:

$$\Delta_L = \frac{2(1+\lambda)(t_L - t_H)\{(1+\lambda_f)A - (2+\lambda_f)c_L + (t_L + t_H)(1/2)\}}{\{(2+\lambda)(2+\lambda_f) - 1\}^2}$$

$$\Delta_H = \frac{2(1+\lambda)(t_L - t_H)\{(1+\lambda_f)A - (2+\lambda_f)c_H + (t_L + t_H)(1/2)\}}{\{(2+\lambda)(2+\lambda_f) - 1\}^2}$$

The optimal tariff under complete information as given by equation (1) in section 1 equals $t(c_L, \lambda, \lambda_f)$ for the low-cost firm and $t(c_H, \lambda, \lambda_f)$ for the high cost firm; further, $t_\theta = t(\tilde{c}, \lambda, \lambda_f)$. Substituting from equation (1) we get that:

$t(c_L, \lambda, \lambda_f) - t(c_H, \lambda, \lambda_f) = (1/\mu_1)(\lambda - \lambda_f)(c_H - c_L)$

$t(c_L, \lambda, \lambda_f) - t_\theta = (1/\mu_1)(\lambda - \lambda_f)(1-\theta)(c_H - c_L)$

$t(c_H, \lambda, \lambda_f) - t_\theta = -(1/\mu_1)(\lambda - \lambda_f)\theta(c_H - c_L)$

(i) To prove the "if" part of the statement in (a), suppose $\lambda \geq \lambda_f$. This implies that $t(c_L, \lambda, \lambda_f) \geq t_\theta \geq t(c_H, \lambda, \lambda_f)$.To check if the optimal tariff scheme is implementable, set $t_L = t(c_L, \lambda, \lambda_f)$ and $t_H = t(c_H, \lambda, \lambda_f)$. Note that this substitution implies (from previous inequality) that $\Delta_L \geq \Delta_H \geq 0$ and $\Pi(t_H, c_H) \leq \Pi(t_\theta, c_H)$, $\Pi(t_L, c_L) \geq \Pi(t_\theta, c_L)$. Now set $Y_L^t = Y_H^t = \Pi(t_\theta, c_H) - \Pi(t_H, c_H) \geq 0$. Note that with this policy, IC_L, IC_H, PC_L and PC_H are all satisfied.

(ii) Now consider the "only if" part of (a): Suppose that $t(c_L, \lambda, \lambda_f)$ and $t(c_H, \lambda, \lambda_f)$ constitute an implementable tariff scheme. This implies that this scheme must satisfy IC_L, IC_H, PC_L and PC_H. Hence, set $t_i = t(c_i, \lambda, \lambda_f)$ for $i \in \{L, H\}$. From IC_L and IC_H this implies that $\Delta_L \geq \Delta_H$. From the equations for Δ_L, Δ_H it is clear that for the previous inequality to hold, it must be the case that $t_L - t_H = t(c_L, \lambda, \lambda_f) - t(c_H, \lambda, \lambda_f) \geq 0$. From the $t(c_L, \lambda, \lambda_f) - t(c_H, \lambda, \lambda_f)$ expression above, the previous inequality implies that $\lambda \geq \lambda_f$. This completes the proof of the first statement in part (a).

(iii) Now consider the second statement in part (a). Suppose $\lambda < \lambda_f$. Consider any possible scheme of tariffs (t_L, t_H). Note that IC_L and IC_H require that $\Delta_L \geq \Delta_H \Rightarrow t_L \geq t_H$. Note that with $\lambda < \lambda_f$, the complete information optimal tariff for the low-cost firm is strictly smaller than for the high cost firm. Concavity of the government's objective function in t_L, t_H then implies that with under the constraint that $t_L \geq t_H$ the optimal solution is $t_L = t_H$. With this holding, the government simply maximizes the expected value of its welfare as in section 2 for which the optimal solution is $t_L = t_H = t_\theta$.

Q.E.D.

Appendix (B2): Proof of *Proposition* 2

Proposition 2: In the quota regime, the complete information solution for the optimal quota (given by equation (2)) is implementable for all plausible values of λ, λ_f.

Proof: For convenience let IC_J (PC_J) denote the incentive compatibility (participation) constraint for the firm when its cost is c_J, $J \in \{L, H\}$. Let $\Omega_L \equiv \Pi(q_L, c_L) - \Pi(q_H, c_L)$ and $\Omega_H \equiv \Pi(q_L, c_H) - \Pi(q_H, c_H)$. $\Omega_{\theta H} \equiv \Pi(q_\theta, c_H) - \Pi(q_H, c_H)$, $\Omega_{\theta L} \equiv \Pi(q_\theta, c_L) - \Pi(q_L, c_L)$.

IC_L can be restated as: $\Omega_L \geq Y_H^q - Y_L^q$, and IC_H is same as: $\Omega_H \leq Y_H^q - Y_L^q$.

PC_L is same as: $Y_L^q \geq \Omega_{\theta L}$ and PC_H is given by $Y_H^q \geq \Omega_{\theta H}$.

Now set q_L, q_H equal to the optimal quota limit as given by equation (2) in section 1. With this holding, we get the following results:

$$\Omega_L = \frac{(c_H - c_L)(6+\lambda)}{2\mu_2}\{A - c_L - A\frac{2+3\lambda}{\mu_2} - \frac{(6+\lambda)(c_H + c_L)}{2\mu_2}\} > 0$$
$$\Omega_H = \frac{(c_H - c_L)(6+\lambda)}{2\mu_2}\{A - c_H - A\frac{2+3\lambda}{\mu_2} - \frac{(6+\lambda)(c_H + c_L)}{2\mu_2}\} > 0$$
$$\Omega_{\theta H} = \frac{(c_H - \tilde{c})(6+\lambda)}{2\mu_2}\{A - c_H - A\frac{2+3\lambda}{\mu_2} - \frac{(6+\lambda)(2c_H - \theta c_H + \theta c_L)}{2\mu_2}\} > 0$$

and $\Omega_{\theta L} < 0$. The last inequality follows from the fact that the optimal quota limit under complete information for the low cost firm (which equals q_L here) is strictly smaller than q_θ (see equation (2)) and that this in turn implies that $\Pi(q_\theta, c_L) < \Pi(q_L, c_L)$ (see Appendix (A2), part (iv)).

Now set $Y_H^q = \Omega_H$ and $Y_L^q = 0$. Noting that $\Omega_L > \Omega_H \geq \Omega_{\theta H}$ and $\Omega_{\theta L} < 0$, it is straightforward to see that both the incentive compatibility and the participation constraints are satisfied for the optimal (complete information) quota scheme.

Q.E.D

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