

Tariffs, Quotas and Forward Contracts under Asymmetric Information

Tigran A. Melkonyan, University of Maryland; and
Harvey E. Lapan, Iowa State University*

Abstract:

We consider optimal trade policy for a large country with private information. We show that the optimal tariff leads to a signaling equilibrium with higher tariffs and lower welfare than under complete information, whereas the optimal import quota replicates the complete information equilibrium and thus is superior to the tariff. We also show that, with the tariff, the country may be better off being uninformed. Finally, we show that if the importing nation cannot commit to its tariff, the use of futures contracts together with the dynamically consistent tariff leads to the same equilibrium as under complete information with commitment.

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* Corresponding author: Harvey E. Lapan, 260 Heady Hall, Iowa State University, Ames, IA 50011;
hlapan@iastate.edu. Phone: 515-294-5917; Fax: 515-294-0221.

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I. Introduction

One of the most prolific literatures in international economics concerns the relationship between tariffs and quotas¹. This literature shows that, while the two tools are equivalent in a deterministic, competitive setting, they yield different equilibria in a number of scenarios, such as when firms possess market power or when there is uncertainty. If the policy-maker faces uncertainty when choosing the policy tool, and if the tool cannot be made contingent on the random variable, then the two policies give rise to different probability distributions of outcomes. While a normative comparison of the two tools requires specifying the economic model and the rationale for commercial policy, the consensus view is probably that tariffs are superior to quotas. This “superiority” of tariffs arises because price and quantity decisions can respond to the realization of the random variable more fully under a tariff than under a quota.

However, the fact that the level of the policy tool may be affected by private information has not been widely discussed. For example, consider a government that can impose import restrictions on a good (e.g., oil), and assume the optimal level of these restrictions depends on government reserves. Suppose that under full information the optimal tariff (or quota) decreases as oil reserves increase. If all parties know the true oil reserves, the government sets the policy tool without considering its impact on expectations concerning reserves, and thus the two policy instruments will be equivalent (if the usual caveats apply). However, if oil reserves are private information, exporters may use the level of the tariff or quota to make inferences concerning the level of reserves. If so, the importing government, when setting the tariff (or quota), will take into account not only the objective being pursued in using this instrument, but also how the level of the instrument affects exporter’s beliefs.

Either the tariff or the quota may serve as a signal about the level of reserves (also called the type) of the importing country. However, the impact on exporting nations of the true type of the importing country differs under the two policies, and thus the two tools will result in different equilibria. In reality, there are numerous situations in which governments, when setting (trade) policy or entering into direct negotiations with foreign buyers or suppliers, have private information which would be relevant in forecasting price (and other aggregates). For example,

¹ The comparison of price-based tools and quantity-based tools is certainly not restricted to the international economics literature. One of the more contemporary areas where this comparison is also germane is in the environmental literature where taxes and command and control regulations are compared.

in commodity markets announcements of past purchases (or lack of purchases) by foreign countries can affect prices. Even in a market-oriented country like Canada, its Wheat Board may simultaneously possess government powers for affecting trade plus private information (such as wheat stocks). Moreover, the strong push toward tariffication in recent GATT (and WTO) negotiations is largely predicated upon the belief that the impact of tariffs is more transparent than that of quotas. Thus, it would seem important to compare the informational implications of each tool.

In this paper we continue the analysis of the signaling role of *different* trade policy instruments. Since any normative comparison of policy instruments must provide a rationale for the use of policy, we work within the context of a large country that uses the tariff, or quota, to improve its terms of trade and domestic welfare. The basic model is the standard two good international trade model, where one large country (US) uses trade policy to improve welfare, whereas all other countries (ROW) pursue free trade. The specific model we use is simplified enough to be tractable, yet rich enough to demonstrate equivalence of tariffs and quotas under full information, and the inferiority of quotas to tariffs under uncertainty. Like Collie and Hviid (1994), we show that the tariff in the signaling equilibrium of the asymmetric information game exceeds that under full information and that both exporting and importing nations are worse off than under complete information. We also show that if the policy-active government uses a quota the resulting outcome is the same as under full information. Thus, quotas are superior to tariffs in an environment where the policy-active government has private information. Since quotas have largely been abolished under GATT/WTO agreements, we also consider other instruments that can be used by the large country, in conjunction with tariffs, to signal reserves.

An important issue is whether the policy-active government has an incentive to commit – if feasible – to its policy before production decisions are made. We show that under asymmetric information welfare in the importing country may increase if the government chooses to set tariffs after production decisions are made, but the resulting welfare must be lower than in the situation of commitment under full information. Thus, if the importing nation could make its private information public and could precommit to a tariff rate before production decisions are made, then the outcome would mimic the full information equilibrium. Since it is very unlikely that the private information is hard (*i.e.*, its revelation cannot be manipulated) this outcome is not feasible. Under these circumstances the following question is important: When the information is

asymmetric and when quotas cannot be used, is there a policy instrument that can restore the importing nation's welfare to the level it has under full information? We show that if the importing nation can sell forward contracts and then set its tariff after production decisions are made, then the answer to this question is positive. Welfare in both the exporting and the importing nations improves as a result of the ability to sell forward.

Our paper is part of a growing literature on trade policy under asymmetric information. The paper most closely related to ours is Collie and Hviid (1994), which is one of the first to analyze the signaling role of tariffs. They use a partial equilibrium model in which a nation imports from a monopolist supplier, and the domestic government uses import tariffs to recapture some of the monopoly rents. Since the government possesses private information about domestic demand, the tariff may signal the consumer type to the foreign monopolist. Due to this signaling effect, the resulting tariff is higher and the country is worse off than under complete information. Note that, even under complete information, the tariff is not the first best policy in this model. Collie and Hviid (1999) analyzes an environment in which the traded good is also produced domestically. Since the domestic firm's marginal cost is assumed known by the domestic government but not by the foreign firm, the government can use the tariff as a signal. The unique separating equilibrium entails a tariff lower than that under complete information; the domestic government uses the tariff to signal the uncompetitiveness of the domestic firm.

In contrast to Collie and Hviid (1994, 1999) and our paper, in which the domestic government has superior information, a number of papers consider strategic trade policy when policy active government(s) are less informed than firms engaged in trade (Qiu (1994), Brainard and Martimort (1996, 1997), and Kolev and Prusa (1999, 2002)). Qiu (1994) extends the basic Brander-Spencer (1985) model by assuming the domestic firm, which competes with a foreign firm in a third market, has private information about its marginal cost. The domestic government decides whether to elicit the domestic firm's private information through offering a menu of policies, or to offer a uniform policy that does not reveal information to the government or the foreign firm. When making this decision the domestic government realizes that the domestic firm's choice of policy is a signal of the domestic firm's competitiveness to the foreign producer. Thus, the model is a combination of screening and signaling. Qiu (1994) shows that eliciting information is preferred when the firms compete in quantities while concealing information is

preferred when they compete in prices. Brainard and Martimort (1997)² also extend the basic Brander-Spencer (1985) model but use a different information structure: both the domestic and foreign firms possess private information. Both the domestic and foreign governments are policy active and use trade instruments to shift profits to their own firms while trying to avoid costly information rent-seeking by these entities. Brainard and Martimort (1997) show that when only the domestic government is policy-active the optimal subsidy is lower than under complete information and the domestic firm may even be strategically disadvantaged. This distortion is mitigated when both governments are policy-active. Kolev and Prusa (1999) analyze a model in which a foreign monopolist, exporting to the home market, is better informed about its own marginal cost and the domestic government is policy active. Under complete information, the domestic government's first-best policy is a discriminatory tariff. Under asymmetric information, the domestic government's ability to use such a discriminatory policy depends on whether the foreign firm's output (signal) in the first period reveals the foreign firm's private information. They show that the unique equilibrium entails pooling by the foreign firm. They also show that home country welfare can be increased if the domestic government can precommit (before any production decisions by the foreign firm) to a uniform tariff or even to free trade. Kolev and Prusa (2002)'s model has informational assumptions similar to their 1999 paper, but employs a different set of policy instruments. In particular, the foreign firm can use voluntary export restraints (VERs) to mask its private information about production costs. The foreign firm does this in anticipation of antidumping protection by the domestic government. They show that under a number of parameterizations of the model the unique equilibrium is pooling, where more efficient types use VERs. This results in an equilibrium tariff that is too high for the inefficient types of competitor and too low for the efficient types.

This paper is organized as follows. In the next section we briefly describe the model and the sequence in which decisions are made, and then solve for the full information equilibrium when the US uses commercial policy to maximize domestic welfare. In section 3 we assume that there is uncertainty concerning US reserves of the import good, that the distribution of reserves is common knowledge, and that the US must choose its policy instrument before anybody learns reserves. In this setting we replicate the standard result that tariffs dominate quotas under uncertainty. In section 4 we assume the US government learns its true reserves before setting

² Brainard and Martimort (1996) contains interesting complementary analysis of similar issues.

policy, but that other countries, when making production decisions, know only the prior distribution of reserves and the actual tariff (or quota) chosen by the US. The results in this section for a tariff parallel those in Collie and Hviid (1994), but we also show that the quota is superior to the tariff. In section 5, we consider the same asymmetric information setting but allow the domestic government to engage in forward transactions. As with the tariff or quota, the amount purchased forward serves as a signal to producers in exporting countries. The ability to purchase forward allows the importing country to achieve the same welfare as in the case in which producers in the exporting countries are completely informed about the level of reserves. We conclude with a discussion concerning the implications of the paper and possible extensions.

2. The Model

We use the simplest general equilibrium model capable of clarifying the roles tariffs or quotas may play as signaling devices. We assume there are two goods, the numeraire good, x , and a second good, y . Furthermore, we assume there is one policy-active large country (the U.S.) that imports good y and exports good x . There is a collection of small identical countries that pursue free trade, and these can be aggregated into a single country (ROW). Agents within each country have identical quasi-linear preferences given by:

$$(1) \quad U = c_x + \left((Ac_y/\gamma) - (c_y^2/2\gamma) \right); \quad \bar{U} = \bar{c}_x + \left((\bar{A}\bar{c}_y/\beta) - (\bar{c}_y^2/2\beta) \right),$$

where (c_x, c_y) , (\bar{c}_x, \bar{c}_y) denote the consumption vectors in the US and ROW, respectively (a “bar” over a variable denotes the ROW). Let $(e_x, 0)$ and $(\bar{e}_x, 0)$ denote the endowment vector of a private agent in the US and ROW, respectively. In addition to private endowments, we assume the US government has reserves of good y , denoted (on a per capita basis) by R . Aggregate per capita US endowments are (e_x, R) . As discussed later, producers in the exporting countries may not know the value of R in the initial stages of the game. Finally, we assume that no production takes place in the US but that in ROW good y can be produced using inputs of the numeraire³:

³ Assuming no US production is a simplifying assumption; introducing competitive US firms with the same information as the government is straightforward. The complication that arises with US production is when the US government has private information not available to ROW or to US producers. The simplifying structure used here makes US agents completely passive and bypasses that issue.

$$(2) \quad (\bar{q}_y^2/2\delta) - \bar{\ell}_x \leq 0,$$

where $\bar{q}_y, \bar{\ell}_x$ denote output of good y and input of good x , respectively, in ROW. Finally, for simplicity, we normalize the number of agents in each country to one.

The demands and indirect utility function for the preferences given in (1) are:

$$(3) \quad c_y^* = A - \gamma p_y; \quad V^* = I + \left((A - \gamma p_y)^2 / 2\gamma \right); \quad \bar{c}_y^* = \bar{A} - \beta \bar{p}_y; \quad \bar{V}^* = \bar{I} + \left((\bar{A} - \beta \bar{p}_y)^2 / 2\beta \right)$$

where (I, \bar{I}) denote income in each country⁴. Foreign income consists of the value of endowments plus the net profits from production, whereas domestic per capita income consists of the value of endowments plus tariff (or quota) revenue:

$$(4) \quad I = e_x + p_y R + (p_y - \bar{p}_y) m_y; \quad m_y = (c_y - R); \quad \bar{I} = \bar{e}_x + (\bar{p}_y \bar{q}_y - [\bar{q}_y^2 / 2\delta]).$$

In (4), m_y denotes US imports of good y , and hence $(p_y - \bar{p}_y) m_y$ is the tariff revenue.

As the full information case serves as a useful benchmark, we start with the following information structure and sequence of decisions. First, the value of US reserves R is learned by all agents. Secondly, the US government irrevocably sets its trade policy. Next, foreign producers make production decisions after observing the level of the US trade policy instrument. Finally, trade and consumption decisions are made and implemented.

Throughout, we assume production decisions are made before consumption decisions. We assume for now that the government can commit to its trade policy, so that no time consistency issues arise⁵. The more important point concerns when the value of R is discovered and by whom. In this section we assume the value of R is known to all agents at the beginning of the game, so there is no uncertainty and no signaling content in trade policy. In the next section we consider *uncertainty*, in which the true value of R is unknown to all at the beginning, and is discovered simultaneously after trade policy and production decisions are made. In sections 4

⁴ We focus on interior solutions and assume the level of income is sufficient to guarantee both goods are consumed. In the US all government revenue, both from endowments (R) and from trade restrictions, is rebated to consumers.

⁵ Without government commitment to trade policy, time consistency issues arise (see Lapan (1988a) and Maskin and Newbery (1990)). Given the inevitable time lag in setting and implementing government policy, it seems reasonable to assume governments cannot revise policy after production decisions are made but before trade takes place.

and 5, where we discuss signaling issues, R will be learned by the government at stage 1, but will not be revealed to other agents until after production decisions are made.

Since information is complete, when foreign producers make production decisions they can perfectly forecast price and hence their supply rule and foreign income are given by:

$$(5) \quad \bar{q}_y^* = \delta \bar{p}_y; \quad \bar{I} = \bar{e}_x + (\delta \bar{p}_y^2 / 2).$$

Using (3), the import demand and export supply equations can be written as:

$$(6) \quad \bar{s}_y = (\delta + \beta) \bar{p}_y - \bar{A}; \quad m_y = (A - R) - \gamma p_y$$

Closing the model requires specifying the level of the trade policy instrument (tariff or quota). As is well-known, the two instruments are identical in this setting. Letting t denote the specific tariff, so that $p_y = t + \bar{p}_y$, equilibrium prices and trade flows are:

$$(7) \quad \bar{p}_y = \frac{A + \bar{A} - R - \gamma t}{\gamma + \sigma}; \quad p_y = \frac{A + \bar{A} - R + \sigma t}{\gamma + \sigma}; \quad \bar{s}_y = \frac{\sigma(A - R) - \gamma(\bar{A} + \sigma t)}{\gamma + \sigma},$$

where $\sigma \equiv \delta + \beta$. We assume $\{\sigma(A - R) - \gamma\bar{A}\} \geq 0$ for all possible values of R . Substituting (7) back into equation (3), using (4)-(7), gives indirect utility for the US in terms of the tariff:

$$(8) \quad V(t) = e_x + \frac{(M + R)^2}{2\gamma} + \frac{R(A + \bar{A} - R)}{\gamma + \sigma} + M(1 - \phi)t - \frac{\gamma\phi(2 - \phi)t^2}{2},$$

where $M \equiv \phi(A - R) - (1 - \phi)\bar{A}$ and $\phi \equiv \frac{\sigma}{(\gamma + \sigma)}$.

The US government chooses tariff t to maximize the indirect utility function $V(t)$. Thus, the optimal tariff, equilibrium prices, imports and welfare are given by:

$$(9) \quad \begin{aligned} t^*(R) &= \frac{M}{(\gamma + \sigma)\phi(2 - \phi)} > 0; \quad m_y^*(R) = \frac{M}{(2 - \phi)}; \quad \bar{p}_y(R) = \frac{\phi(A - R) + \bar{A}}{\phi(2 - \phi)(\gamma + \sigma)}; \\ p_y(R) &= \frac{2(A - R) + \bar{A}}{(2 - \phi)(\gamma + \sigma)}; \quad V^*(R) = e_x + \frac{(M + R)^2}{2\gamma} + \frac{R(A + \bar{A} - R)}{\gamma + \sigma} + \frac{M^2(1 - \phi)}{2(\gamma + \sigma)\phi(2 - \phi)} \end{aligned}$$

The solution has these properties: (i) the optimal specific tariff is a monotonically decreasing function of government reserves R ; (ii) optimal imports, and thus the optimal quota, are a decreasing function of R ; and (iii) the world and domestic price are monotonically decreasing functions of R . Note that the equilibrium is the same for an optimal tariff or quota.

Before considering the signaling role of trade policy, we briefly review what happens if uncertainty is present when government trade policy and foreign production decisions are made.

3. The Optimal Tariff and Quota under Uncertainty

In this section we modify the information structure and sequence of actions as follows:

Stage 1: The US government irrevocably sets trade policy, given the common knowledge concerning the distribution of reserves;

Stage 2: Foreign producers make production decisions;

Stage 3: The true value of reserves is revealed to all parties;

Stage 4: Trade and consumption decisions are made and implemented.

We assume R is distributed on the interval $[\underline{R}, \bar{R}] \subset \mathcal{R}$. The non-equivalence of tariffs and quotas with this information structure is well-known. The sole purpose of this section is to motivate the next section.

We simultaneously consider both the tariff and the quota equilibria. Denote the specific tariff by t and the quota by L . Given the levels of the trade instrument, foreign production and reserves, equilibrium world and domestic prices and imports for each case are given by:

$$(10) \quad \bar{p}_y^q(L) = \frac{L + \bar{A} - \bar{q}_y}{\beta}; \quad p_y^q(L, R) = \frac{A - L - R}{\gamma}; \quad m_y^q(L) \equiv L$$

$$(11) \quad \bar{p}_y^t(t, R) = \frac{A + \bar{A} - R - \bar{q}_y - \gamma t}{\gamma + \beta}; \quad p_y^t(t, R) = (\bar{p}_y^t + t); \quad m_y^t(t, R) = \frac{\beta(A - R) - \gamma(\bar{A} - \bar{q}_y + \beta t)}{(\gamma + \beta)}$$

where the superscript “ q ” in (10) refers to the case of a quota whereas the superscript “ t ” in (11) refers to the case of a specific tariff⁶. Note that, with a quota, world prices do not depend on realized reserves; thus, foreign producers do not need to know actual reserves to forecast world price⁷. With a tariff, world prices depend on actual reserves and the tariff, and thus foreign output depends on beliefs concerning the distribution of R . In this section, since trade policy is chosen before R is known, the tariff does not modify the producers’ beliefs, but in the next section this will no longer be the case.

Due to risk-neutrality and the model’s quadratic structure, output depends on expected prices: $\bar{q}_y^* = \delta \bar{p}_y^e$, where \bar{p}_y^e is the expected price conditional on information available when production decisions are made. For a quota, there is no uncertainty as expected and realized *world* prices are the same; in the case of a tariff, due to the linear structure of the price forecast, the expected price depends only upon expected reserves. Thus, solving for each case we have:

$$(12) \quad \bar{q}_y^q = \frac{\delta(L + \bar{A})}{\sigma}; \quad \bar{p}_y^q = \frac{(L + \bar{A})}{\sigma}; \quad p_y^q(L, R) = \frac{A - L - R}{\gamma};$$

$$(13) \quad \bar{p}_y^e = \frac{A + \bar{A} - R^e - \gamma t}{\gamma + \sigma}; \quad \bar{q}_y^t = \delta \bar{p}_y^e; \quad \bar{p}_y^t = \bar{p}_y^e - \frac{\varepsilon}{(\gamma + \beta)}; \quad p_y^t = \bar{p}_y^e + t - \frac{\varepsilon}{(\gamma + \beta)},$$

where $R^e \equiv E(R)$ and $\varepsilon \equiv (R - R^e)$.

For each case, the optimal policy is found by substituting the equilibrium price relations and import revenue into the indirect utility function and maximizing expected utility over the policy instrument. Since the first order conditions are linear, the solution for each case depends only on the expected reserves, and *certainty equivalence* holds for the policy instruments. Let

$t^q \equiv p_y^q - \bar{p}_y^q = \frac{\sigma(A - L - R) - \gamma(L + \bar{A})}{\gamma\sigma}$ denote the tariff-equivalent under the quota. Performing

the optimization yields the following:

⁶ It is well-known that *ad valorem* and specific tariffs are not equivalent under uncertainty. We consider only the specific tariff and quota cases.

⁷ As is common, we assume the quota binds for all R ; if it did not, then world price would depend on R when the quota was not binding.

$$(14) \quad L^* = \frac{M^e}{(2-\phi)}; \quad E(V^q) = V^*(R^e) - \frac{Var(R)}{2\gamma}; \quad t^q(R) = t^* - \frac{(R-R^e)}{\gamma};$$

$$(15) \quad t^* = \frac{M^e}{(\gamma+\sigma)\phi(2-\phi)}; \quad E(V^t) = V^*(R^e) - \frac{(\gamma+2\beta)Var(R)}{2(\gamma+\beta)^2}; \quad m_y^t(R) = L^* - \frac{\beta(R-R^e)}{(\gamma+\beta)};$$

where $M^e \equiv [\phi(A-R^e) - (1-\phi)\bar{A}]$, $V^*(R^e)$ denotes maximized US utility when $R \equiv R^e$ (from equation (9)) and $Var(R)$ is the variance of R . As is well-known, the tariff yields strictly higher expected utility ($\beta > 0$). Although not shown here, it is clear that exporting countries are also better off in the case of the tariff due to the (strict) convexity of the indirect utility function in (export) price. The conclusion follows since expected price is the same under the two regimes, but export price is deterministic under the quota, but stochastic under the tariff.

4. Tariffs and Quotas as Signaling Devices

We now consider the signaling role of tariffs and quotas under asymmetric information. In particular, the information structure and the timing of decisions are as follows:

Stage 1: The value of R is learned by the government but is not revealed to foreign agents⁸.

Stage 2: The US government irrevocably sets trade policy (tariff or quota).

Stage 3: Foreign producers make production decisions based upon their prior beliefs concerning R and the observed level of the trade policy instrument.

Stage 4: The true value of R is revealed to all agents.

Stage 5: Trade and consumption decisions are made and implemented.

This decision structure differs from the case of uncertainty as the government learns its true reserves before setting policy, and it differs from the full information case as foreign producers do not learn the true value of R until after production decisions are made. It is these differences that result in the US government's trade policy being a potential signal of reserves. Note that an equivalent information structure would be to assume the US government had private information about the US import demand intercept, but reserves were common knowledge. All the results would remain valid; only their interpretation would have to be modified accordingly.⁹

⁸ Since US private agents are completely passive in the model it is immaterial when they learn the true value of R .

⁹ We thank an anonymous referee for this observation.

Consider first the optimal quota. As previously noted, under a quota foreign prices depend only upon the quota level and not upon the true level of reserves. Thus, it is irrelevant to foreign producers whether the quota accurately reveals true reserves. Even if the quota fully reveals the level of reserves, the equilibrium is unaffected by the fact the quota serves as a signal.

Since foreign production under the quota does not depend on US reserves, the US government has no incentive to misrepresent its type. Thus, the equilibrium under the quota is exactly the same as when both parties are initially informed about the true level of reserves. This equilibrium is given by (9), with the optimal quota given by: $L^*(R) = (M/(2-\phi))$.

Next, consider the incentive structure under the tariff¹⁰. The US government choice of tariff $t(R)$ may depend on its private information R . After observing the tariff, foreign producers make an inference about the true level of US reserves. We let $r(t)$ denote the updated beliefs of foreign producers about US reserves. If foreign producers can perfectly infer the level of reserves R , then we will say that the equilibrium is separating.

Under a tariff, realized foreign price depends on the tariff, the level of foreign production, and the true value of reserves. Thus, actual reserves (potentially) affect foreign production decisions in two ways – through the tariff, which is known when production decisions are made, and through the realized price – which is not known, but may be inferred from the tariff.

We solve backward to determine the equilibrium. Given production levels, the tariff and the realized value of reserves, foreign prices are given by equation (11). Foreign producers make their output decision based on their forecast of the future foreign price:

$$(16) \quad \bar{q}_y = \delta E(\bar{p}_y | t) = \delta \left\{ (A + \bar{A} - r(t) - \bar{q}_y - \gamma t) / (\gamma + \beta) \right\}$$

where $E(\bar{p}_y | t)$ is the expected foreign price conditional on the announced tariff rate. Note that the tariff has two distinct effects on this output decision: (1) the direct effect on foreign prices; and (2) the inferential effect, captured by $r(t)$, as the announced tariff rate may affect inferences made by foreign producers about reserves, and hence world price. Simplifying (16) yields foreign output, foreign price, and trade flows, given tariffs, beliefs and realized reserves:

¹⁰ We consider only a specific tariff. With an *ad valorem* tariff there may not be a separating equilibrium; *e.g.*, in our model, if $\bar{A} = 0$, $\beta = 0$, so there is no foreign consumption of y , the optimal *ad valorem* tariff is independent of R .

$$(17) \quad \bar{q}_y = \delta \left\{ \frac{A + \bar{A} - r(t) - \gamma t}{\gamma + \sigma} \right\}; \quad \bar{p}_y^t(t, R) = \left(\frac{A + \bar{A} - R - \gamma t}{\gamma + \sigma} \right) - s\Delta; \quad m_y = M - \gamma\phi t + \gamma\Delta,$$

where $\Delta \equiv R - r(t)$, $\alpha \equiv \frac{\delta}{\delta + \beta}$; $s \equiv \frac{\alpha\phi}{(1 - \alpha\phi)(\gamma + \sigma)}$ and M is as defined earlier. The term $\alpha \in [0, 1]$ reflects the fraction of the slope of the export supply curve that is due to the price responsiveness of production. From (17) we see that, *ceteris paribus*, forecasts of lower reserves lead to more foreign output and hence –due to this increased output - a *lower* world price. By comparing (17) to equation (7), we see that equilibrium imports for this case differ from the full information case only by the term $(\gamma\Delta)$ on the right hand side of (17). Thus, in a separating equilibrium imports, *as a function of t*, will be the same as under full information (though actual imports will differ if the tariff differs). Note that the responsiveness of foreign exports to the tariff, as viewed by the importing nation, will differ from the perfect foresight case if the government believes that the foreign producers' forecast of R depends on the tariff rate.

Finally, substituting all the preceding into the US' indirect utility function gives US utility as a function of actual reserves, the tariff rate, and the belief function:

$$(18) \quad V(t) = e_x + p_y R + t m_y + \left[(A - \gamma p_y)^2 / 2\gamma \right]; \quad p_y = \bar{p}_y + t$$

where (m_y, \bar{p}_y) are given in (17). This expression differs from the full information case only in that prices and imports depend upon Δ , the forecasting error made by producers. In a separating equilibrium (that is, when there is no forecasting error) realized prices, quantity and hence utility will be the same as under full information *if* the tariff is the same.

Rewriting (18) as a function of the tariff t , the foreign output level \bar{q}_y , and reserves R , we obtain the following expression for the indirect utility of a representative domestic agent¹¹

$$(19) \quad \tilde{V}(R, \bar{q}_y, t) = b_0 + b_1 R + b_2 \bar{q}_y + b_3 t + b_4 R^2 + b_5 \bar{q}_y^2 + b_6 t^2 + b_7 R \bar{q}_y + b_8 R t + b_9 \bar{q}_y t.$$

The US government's problem of setting trade policy is a dynamic game where foreign producers maximize expected profits and the US government's objective function is given by (19). In this game, the importing nation of any type wants to persuade foreign producers that it

has low reserves. Since, under full information the tariff rate is inversely related to the level of reserves, a high tariff may signal a low level of reserves. If the US government with relatively low reserves sets the same tariff rate as under full information, then types with larger reserves may want to mimic the low reserve government's behavior. Thus, to separate from these types the low reserve type may want to increase its tariff above the full information level (thus making imitation more costly). In other words, we intuitively expect that, similarly to Collie and Hviid (1994), a fully separating equilibrium might exist in which tariffs are monotonically declining in reserves and tariff levels are, in general, higher than in the full information setting. To support our intuition we solve for the sequential equilibrium of our game, which is defined as follows.

Definition: A sequential equilibrium consists of strategies $t(R)$ and $\bar{q}_y(t)$ and beliefs $r(t)$ ¹² such that:

- (i) The importing government chooses $t(R)$ to maximize the ex ante indirect utility function $\tilde{V}(R, \bar{q}_y(t), t)$ for all R ;
- (ii) Foreign producers choose output that maximizes their expected profits given beliefs $r(\cdot)$. This output level is given by $\bar{q}_y(t) = \delta \left\{ \left(A + \bar{A} - r(t) - \gamma t \right) / (\gamma + \sigma) \right\}$; and
- (iii) Foreign producers' beliefs $r(\cdot)$ on the equilibrium path are determined by Bayes' rule given the prior probability over the importing government's types and the importing government's equilibrium strategy $t(R)$.

Let $V(R, r, t)$ denote the indirect utility of the representative domestic agent when the domestic government's true type is R , foreign producers' inference about its type is r and tariff t is chosen. Substituting the expression for $\bar{q}_y(t)$ into $\tilde{V}(R, \bar{q}_y(t), t)$ it is easy to verify that¹³

$$(20) \quad V(R, r, t) = a_0 + a_1 R + a_2 r + a_3 t + a_4 R^2 + a_5 r^2 + a_6 t^2 + a_7 Rr + a_8 Rt + a_9 rt .$$

¹¹ The definitions of parameters b_0, \dots, b_9 are given in Appendix 2.

¹² $r(\cdot)$ is a probability distribution over $\left[\underline{R}, \bar{R} \right]$.

¹³ The definition of parameters a_0, \dots, a_9 in equation (20) are given in Appendix 2.

Let $t^*(R)$ denote the optimal tariff when foreign producers are completely informed about domestic reserves and the domestic government can precommit to its trade policy instrument. From Section 2, we have that $t^*(R) = [M(R)/\sigma(2-\phi)]$. In Appendix 1 we prove the following lemma¹⁴.

Lemma 1: In any separating equilibrium of the game, $t(\bar{R}) = t^*(\bar{R})$.

The intuition behind the lemma is straightforward. The worst beliefs, from the US government's perspective, that foreign producers may have about US reserves, both on and off the equilibrium path, is given by \bar{R} . Hence, a deviation from $t^*(\bar{R})$ cannot be credibly punished.

Mailath (1987) has identified conditions on the signaling parties' utility function that ensure uniqueness of the separating equilibrium. Using his results, the proof of the following proposition is found in Appendix 1:

Proposition 1: Suppose that the equilibrium triplet $(t(\cdot), \bar{q}_y(\cdot), r(\cdot))$ is fully separating, and suppose that the initial value condition $t(\bar{R}) = t^*(\bar{R})$ holds (Lemma 1). Then

(i) $t(R)$ is continuous and strictly decreasing on $[\underline{R}, \bar{R}]$. It is differentiable on (\underline{R}, \bar{R}) and satisfies the differential equation

$$(21) \quad \frac{dt}{dR} = \left(\frac{\delta}{\gamma(\beta + \gamma)} \right) \left(\frac{\phi(A - R) - (1 - \phi)\bar{A} + \gamma(1 - \phi)t}{\phi(A - R) - (1 - \phi)\bar{A} - \sigma(2 - \phi)t} \right) = \left(\frac{\delta}{\gamma(\beta + \gamma)} \right) \left(\frac{M + \gamma(1 - \phi)t}{M - \sigma(2 - \phi)t} \right).$$

(ii) The solution to the differential equation (21) coupled with the initial value condition $t(\bar{R}) = t^*(\bar{R})$ is unique.

Thus, the signaling game has a unique separating equilibrium given by (21) together with the initial value condition $t(\bar{R}) = t^*(\bar{R})$. Although $t(R)$ is the unique separating equilibrium it is not the unique sequential equilibrium of the signaling game, as the game also has pooling equilibria where some types pool at the same tariff rate. However, only the unique separating equilibrium

¹⁴ All proofs are given in Appendix 1.

survives the universal divinity criterion of Banks and Sobel (1987). This criterion applied to our game implies that if foreign producers observe out-of-equilibrium tariff rates their posterior beliefs place positive probability only on types that are most likely to deviate from the equilibrium. The proof that the unique sequential equilibrium satisfying the universal divinity criterion is separating is similar to the proof of a similar result in the game of investment and rate regulation in Besanko and Spulber (1992). Thus, we omit details of the proof and only outline its structure. As a first step, one can show that the tariff schedule $t(R)$ is non-increasing in R for any sequential equilibrium satisfying the universal divinity criterion. Using this result, we can demonstrate that at any sequential equilibrium satisfying the universal divinity criterion, the foreign exporters put probability one on the type $R = \bar{R}$ for off-the-equilibrium path tariff rates $t < t(\bar{R})$. Also, for off-the-equilibrium path tariff rates $t > t(\underline{R})$, the foreign exporters assign probability one to the event $R = \underline{R}$. Finally, these results can be used to prove that the unique sequential equilibrium satisfying universal divinity criterion is fully separating. Interestingly, Kolev and Prusa (2002) also use universal divinity criterion to refine the set of equilibria. In contrast to our paper, the only equilibrium that survives this criterion in their model is pooling.

The universal divinity criterion is not a unanimous choice as a refinement of sequential equilibria in signaling games. The potential logical difficulty with Banks and Sobel (1987)'s universal divinity criterion and Cho and Kreps (1987) intuitive criterion, which is close in spirit to universal divinity, is that both refine disequilibrium beliefs without taking into account the implications of these refined beliefs for behavior along the equilibrium path. Mailath et al. (1993) attempt to address this shortcoming by introducing an alternative solution concept, called *undefeated equilibrium*. Loosely stated, a pure-strategy sequential equilibrium is undefeated if there does not exist an alternative pure-strategy sequential equilibrium such that a non-empty set of types could gain by deviating to a message (not sent by any type in the suspect equilibrium) if such a deviation resulted in modification of beliefs consistent with the alternative equilibrium. Although this alternative solution concept is not directly applicable in our model¹⁵, one could refine the set of sequential equilibria following the general program of Mailath et al. (1993)¹⁶. In particular, when R has a narrow support it is possible to demonstrate that the only undefeated

¹⁵ Mailath et al. (1993) are dealing with the case of finite types while our model has a continuum of types.

equilibria are pooling. However, pooling equilibria are not always the only undefeated equilibria and for certain distributions of R the separating equilibrium is not defeated by any pooling equilibrium. Although we have argued above for the plausibility of the universal divinity criterion, and thus singled out the unique separating equilibrium as the most plausible mode of behavior, picking a refinement to narrow down the set of potential equilibria is ultimately a judgment call. Notice that even if one adopts an equilibrium refinement in the spirit of Mailath et al. (1993), thus discarding separating equilibrium for certain distributions of R , this section's main qualitative finding that quotas dominate tariffs under asymmetric information remains valid because the pooling equilibrium outcome, similarly to the separating equilibrium outcome, is distorted from the first-best while quotas achieve the complete information first-best.¹⁷

In what follows, we mainly concentrate on the separating equilibrium outcome. The following proposition verifies our intuition on the relationship between the tariffs under full and incomplete information. Proof is provided in Appendix 1.

Proposition 2: The tariff $t(R)$ in the unique separating equilibrium is strictly greater than the full-information tariff $t^*(R)$ for all $R \in [\underline{R}, \bar{R})$.

Equilibrium tariffs are higher under asymmetric information since the government has an incentive to misrepresent its type. The more price-responsive is foreign output, the greater is the government's incentive to misrepresent its type. The higher tariff implies that both importing and exporting nations are worse off than under full information. Thus, the signaling equilibrium is *Pareto inferior* to the full information equilibrium and hence to the quota.

Corollary: In the asymmetric information game described here, all parties prefer quotas to tariffs.

These results are similar, in spirit and intuition, to the problem that arises with an inability to commit to tariffs. In the latter case, governments have an incentive to revise tariffs

¹⁶ Collie and Hviid (1994) compare welfare in the complete information case with that in the pooling and separating equilibria. Similar analysis could be performed for our model to identify the set of lexicographically maximum sequential equilibria (Mailath et al. (1993)) which are undefeated.

¹⁷ We are indebted to an anonymous referee for raising this point and stimulating the discussion in this paragraph.

after production decisions are made; since foreign producers anticipate this, they reduce output, leading to a higher tariff equilibrium that is Pareto inferior to the commitment equilibrium.

From the preceding it is not clear how the importing nation is affected by knowing its true reserves before choosing its tariff – *i.e.*, how *ex ante* expected welfare under asymmetric information compares to that under uncertainty. Clearly, when a quota is used, expected welfare under asymmetric information is higher than under uncertainty since the quota equilibrium replicates the full information equilibrium.

In general, the signaling equilibrium tariff is non-linear and expected utility for the two cases is not readily compared. However, for the special case in which the smallest tariff is zero ($t^{fi}(\bar{R}) = 0$), the tariff under signaling is linear in reserves. For this case the tariff rules are¹⁸:

$$(22) \quad t^{fi} = (M(R)/\sigma(2-\phi)); \quad t^u = (M(R^e)/\sigma(2-\phi)); \quad t^{si} = \varpi_1 t^{fi};$$

$$\varpi_1 = \left(\left[(1+\xi) + \sqrt{(1+\xi)^2 + 4\xi\mathcal{G}} \right] / 2 \right) > 1; \quad \xi \equiv (\alpha(1-\phi)/(1-\alpha\phi)); \quad \mathcal{G} = (\phi(2-\phi)/(1-\phi)^2)$$

where the superscripts refer to full information, uncertainty, and the signaling equilibrium, respectively. For this case realized welfare under the signaling equilibrium is given by:

$$(23) \quad V^*(R) = e_x + \frac{(M+R)^2}{2\gamma} + \frac{R(A+\bar{A}-R)}{\gamma+\sigma} + \frac{M^2(1-\phi)\varpi_1(2-\varpi_1)}{2(\gamma+\sigma)\phi(2-\phi)}$$

Clearly, $E(V^{fi}) > \text{Max}\{E(V^u), E(V^{si})\}$; comparing $E(V^u)$ and $E(V^{si})$ yields, after simplification:

$$(24) \quad E[V^{si} - V^u] = \left\{ \left[\frac{(1-\phi)\phi^2(2\varpi_1 - \varpi_1^2)}{2\sigma(2-\phi)} + \frac{\delta(\beta + \phi(\gamma + \beta))}{(\gamma + \beta)^2} \right] \text{Var}(R) - \frac{(M^e)^2(1-\phi)(\varpi_1 - 1)^2}{2\sigma(2-\phi)} \right\}$$

¹⁸Let the equilibrium tariff under signaling be: $t^{si}(M) = \mu(M)t^{fi}$, where t^{fi} is the full information tariff. In general, $\mu(M)$ is given by: $\left((\varpi_1 - \mu(M))/(\varpi_1 - 1) \right)^\pi \left((\mu - \varpi_2)/(1 - \varpi_2) \right)^{(1-\pi)} = (\underline{M}/M)$. ϖ_1, ϖ_2 are the roots of: $(x^2 - (1+\xi)x - \xi\mathcal{G}) = 0$, and ξ, \mathcal{G} are defined in (22); thus, $\varpi_1 > 1, \varpi_2 < 0$. \underline{M} is the value of M at the highest level of reserves $\underline{M} \equiv (\phi(A - \bar{R}) - (1-\phi)\bar{A})$, and $\pi \equiv ((\varpi_2 - 1)/(\varpi_1 - \varpi_2)) \in [0, 1]$.

where $\varpi_1 > 1$ since tariffs are higher under the signaling equilibrium than under full information. If ϖ_1 is close to one (α close to zero) and/or the $Var(R)$ is large relative to the expected value of M , then the signaling equilibrium will yield higher expected utility than the case of uncertainty since the costs due to signaling will be relatively low. However, in other cases the signaling equilibrium yields lower expected utility for the informed agent, implying that the information concerning reserves has a negative (expected) value for the policy-active importing nation. Finally, note that the country may be worse off in the signaling equilibrium than under free trade – as can also happen if commitment is not feasible. Realized home welfare under free trade is given by (23), with $\varpi_1 = 0$. Thus:

Proposition 3. If $\varpi_1 > 2$ the signaling equilibrium leads to lower welfare than free trade¹⁹.

5. Time-consistency of Trade Policy and Forward Contracts

In this section we study what happens when the US government cannot irrevocably commit its trade policy before production decisions are made. We consider only two informational environments: the full information case and the case in which the US government has superior information. It is well known (see Lapan (1988a), Maskin and Newberry (1990)) that in the full information case both the importing and exporting countries are worse off due to this inability to precommit. If the US government can revise its announced policy after foreign production decisions have been made but before trade decisions are made, the ex ante optimal tariff (derived in Section 2) is not time-consistent. The time-consistent solution (i.e., when foreign producers' forecast of the future tariff rate is correct) entails a lower level of imports and a higher tariff rate than when the policy-active government can precommit. However, under asymmetric information the ability of the importing government to revise its announced trade policy after production decisions may benefit both the importing and the exporting nations²⁰.

¹⁹ $\varpi_1 \geq 2$ implies: $\alpha \geq \left[\frac{2(1-\phi)}{2-\phi^2} \right]$. For example, if the slope of the domestic import demand schedule equals the slope of the foreign export supply schedule ($\phi = .5$), then $\alpha \geq (4/7)$ suffices.

²⁰ If the domestic government cannot precommit to its tariff before production decisions are made and if it does not have any other policy instruments (e.g., production or consumption taxes or subsidies) and cannot offer forward contracts, the ex post tariff is given by $t^c(R, R^e) = (1/d) \left\{ \left[(\beta + \delta)A - \gamma \bar{A} \right] - (d/(\beta + 2\gamma))R - (\gamma\delta/(\beta + 2\gamma))R^e \right\}$,

In what follows we assume that the policy-active government sets its final tariff after foreign exporters' production decisions. Lapan (1988b) demonstrates, under complete information, that if the policy-active government can use forward contracts an ex ante optimal solution can be restored. It is interesting to consider the role of forward contracts when the trading parties are asymmetrically informed. In this case, forward contracts have an additional role of serving as a signal to foreign producers. For this reason, we consider the following sequence of decisions to investigate the role of forward contracts as signaling devices.

Stage 1: The level of US reserves R is learned by the government but is not revealed to foreign agents.

Stage 2: The US government decides on the number of forward contracts to be bought forward.

Stage 3: Foreign producers make production decisions based upon their prior beliefs concerning R and the actual number of contracts purchased forward.

Stage 4: The US government sets its tariff.

Stage 5: The true value of R is revealed to all agents.

Stage 6: Trade and consumption decisions are made and implemented.

Let F denote the number of forward contracts bought by the US government and let p_y^F denote the price specified in the contracts. The government's choice of the number of forward contracts $F(R)$ is a function of its private information R . After observing F foreign producers make an inference about the true level of R . We let $r(F)$ denote the updated beliefs of foreign producers about US reserves. Similarly to the previous section, we solve the game backward.

Domestic per capita income is given by

$$(25) \quad I = e_x + p_y R + (p_y - \bar{p}_y) m_y + (\bar{p}_y - \bar{p}_y^F) F .$$

Note that in any separating equilibrium of the game the forward price \bar{p}_y^F is equal to the spot price \bar{p}_y . Otherwise, one of the trading parties would be unwilling to trade forward. Given the predetermined output levels, the tariff, and the realized value of R , foreign prices are given by (11): $\bar{p}_y^t(t, R) = \left((A + \bar{A} - R - \bar{q}_y - \gamma t) / (\gamma + \beta) \right)$. Substituting this expression into the US'

where "d" is defined below equation (30). It can be verified that under many parameterizations the domestic government prefers to set its tariff after production decisions are made.

utility function and optimizing over the tariff rate we get the ex post optimal tariff rate as a function of contracts traded forward, the actual reserves and the foreign producers' output:

$$(26) \quad t = \left[\left(\beta(A - R) - \gamma(\bar{A} - \bar{q}_y) - (\beta + \gamma)F \right) / \beta(\beta + 2\gamma) \right]$$

When foreign producers make their output decision they use their forecast of the future tariff and foreign price

$$(27) \quad \bar{q}_y = \delta \left\{ \left(A + \bar{A} - r(F) - \bar{q}_y - \gamma t \right) / (\gamma + \beta) \right\}$$

where t is the tariff rate in (26). Solving (27) for \bar{q}_y we obtain

$$(28) \quad \bar{q}_y = \delta \left\{ \left(\beta(A - r(F)) + (\beta + \gamma)\bar{A} + \gamma F \right) / (\beta(\beta + 2\gamma) + \delta(\beta + \gamma)) \right\}$$

As for the tariff in the preceding section, forward contracts have two effects on the production decisions of foreign exporters, the direct and the inferential effects. Substituting (28) into (26) we obtain the ex post optimal tariff as a function of the domestic government's true type R , foreign producers' beliefs r and the number of forward contracts, F :

$$(29) \quad t = \frac{1}{\beta(\beta + 2\gamma) + \delta(\beta + \gamma)} \left\{ (\beta + \delta)A - \frac{\beta(\beta + 2\gamma) + \delta(\beta + \gamma)}{\beta + 2\gamma} R - \frac{\delta\gamma}{\beta + 2\gamma} r(F) - \gamma\bar{A} - (\beta + \gamma + \delta)F \right\}$$

When performing the above manipulations we implicitly assumed that the US government knows foreign producers' beliefs, foreign producers know that the US government knows, and so on ad infinitum. As is well known, any sequential equilibrium should satisfy this requirement.

Finally, substituting all the preceding into the US' indirect utility function gives US utility as a function of actual reserves, the number of forward contracts, and the belief function:

$$(30) \quad V(R, r, F) = c_0 + c_1 R + c_2 r + c_3 F + c_4 R^2 + c_5 r^2 + c_6 F^2 + c_7 Rr + c_8 RF + c_9 rF,$$

where $d \equiv \beta(\beta + 2\gamma) + \delta(\beta + \gamma)$, and the parameters c_0, \dots, c_9 are defined in Appendix 2.

The strategic interaction between the US government and the foreign producers is a signaling game, where the foreign producers' output rule, given the beliefs, is given by (28) and the US government maximizes the indirect utility function of its representative agent. As in the preceding section, the US government wants to convince foreign producers that it has low

reserves. Under full information, the number of forward contracts $F^*(R)$ offered by the US government is given by $F^*(R) = (\alpha M(R)/(2 - \phi))$. The resulting tariff rate and the welfare of importing and exporting nations are the same as in the full information case of Section 2. Note also that the number of forward contracts is inversely related to the level of reserves. Thus, a large number of forward contracts may signal a low level of reserves.

We want to investigate whether in the asymmetric information setting a separating equilibrium exists and how it is related to the full information forward contracts and tariff. It is straightforward to verify that the indirect utility function in (30) satisfies properties (1)-(5) from Mailath (1987). However, it does not satisfy the single-crossing property. More precisely, $[(\partial V/\partial r)/(\partial V/\partial F)] = -(\beta/\gamma)$ which is invariant to changes in R . Moreover, the initial value condition $F(\bar{R}) = F^*(\bar{R})$ is not satisfied. The solution to the differential equation²¹ $(dF/dR) = (\beta/\gamma)$, given the initial value condition, is not an equilibrium since type \bar{R} has an incentive to deviate from its strategy. Thus, the results from Mailath (1987) do not apply to this case. The separating equilibrium of the game is found by differentiating²² (30) with respect to F and equating the derivative to 0. The resulting equation has two solutions. The first is the solution $(dF/dR) = (\beta/\gamma)$, but the second-order conditions are not satisfied at this solution. The second solution is the full information level of forward contracts $F^*(R)$. It is straightforward to verify that this strategy constitutes a part of a sequential equilibrium. Substituting for F in (29) one can easily verify the optimal tariff is equal to the optimal tariff under full information (equation (9) in Section 2). Thus, when the US government can purchase forward and has an ability to revise its tariff after production decisions are made, the unique separating equilibrium outcome is the same as under full information (Section 2).

Proposition 4. Under asymmetric information and assuming the policy active government cannot precommit to its tariff, the use of forward contracts leads to a sequential equilibrium that replicates the full information commitment equilibrium.

²¹ The solution to this differential equation when the initial value condition is satisfied is given by

$$F(R) = \frac{1}{\beta + 2\gamma + \delta} \left[\frac{\delta[(\beta + \delta)A - \gamma \bar{A}]}{\beta + \delta} - \frac{d}{\gamma} \frac{1}{R} \right] + \frac{\beta}{\gamma} R, \text{ which is the same as under complete information.}$$

²² Note that that foreign producers' beliefs r are a function of forward contracts F .

6. Conclusion

It is a fundamental premise of international negotiations that tariffs are superior to quotas as trade restrictions. One reason for this belief is that tariffs are thought to be more transparent. We have shown that, in the context of asymmetric information, tariffs are inferior to quotas. The informational content of tariffs induces governments with private information to use higher tariffs in order to signal their type. The resulting tariff equilibrium is more restrictive than the quota equilibrium since, with quotas, foreign exporters do not care about the type of the foreign government, once trade volumes are known. Since the quota's signaling role is unimportant, it can support the full information equilibrium. We have also seen that, with tariffs and asymmetric information, the inability to precommit tariffs does not necessarily lower welfare. In fact, we have shown that – as in the full information case – the use of forward contracts with the dynamically consistent tariff supports the full information commitment equilibrium.

Our results are somewhat analogous to the old literature on the relative ability of tariffs and quotas to insulate countries from domestic, or foreign, disturbances. In our paper, since the “disturbance” (i.e., the private information) is internal, the quota effectively isolates foreign countries from this disturbance, and therefore the signaling aspect of the quota is unimportant to foreigners. Naturally, this raises the question of how these instruments compare when the quota does not completely insulate foreign producers from disturbances, such as when the private information possessed by the US government also concerns foreign disturbances.

A final question that occurs is how the presence of asymmetric information affects the conclusion that tariff negotiations can, in conjunction with market access commitments, lead to efficient outcomes that do not require contracting on domestic policy (as, for example, in Bagwell and Staiger (2001)). Since market access commitments, like quotas, are (implicit) contracts on trade volumes, the combination of tariff and quantitative commitments, which are used to avoid contracting on domestic policies, may have to be rethought in situations with asymmetric information.

Appendix 1

Proof of Lemma 1: Suppose that $t(\bar{R}) \neq t^*(\bar{R})$ is the equilibrium strategy of type- \bar{R} government. The equilibrium payoff is given by $V(\bar{R}, \bar{R}, t(\bar{R}))$. Consider a deviation of the government to a strategy $t^*(\bar{R})$. The payoff for this strategy is given by

$$V(\bar{R}, r(t^*(\bar{R})), t^*(\bar{R})) = a_0 + a_1 \bar{R} + a_2 r(t^*(\bar{R})) + a_3 t^*(\bar{R}) + a_4 \bar{R}^2 + a_5 [r(t^*(\bar{R}))]^2 \\ + a_6 [t^*(\bar{R})]^2 + a_7 \bar{R} r(t^*(\bar{R})) + a_8 \bar{R} t^*(\bar{R}) + a_9 r(t^*(\bar{R})) t^*(\bar{R})$$

In what follows we replace $r(t^*(\bar{R}))$ by r to simplify our notation. Thus, the gain to this deviation is given by

$$\Delta = a_2 r + a_5 r^2 + a_7 r \bar{R} + a_3 t^*(\bar{R}) + a_8 \bar{R} t^*(\bar{R}) + a_9 r t^*(\bar{R}) + a_6 [t^*(\bar{R})]^2 \\ - \left\{ a_2 \bar{R} + a_5 \bar{R}^2 + a_7 \bar{R}^2 + a_3 t(\bar{R}) + a_8 \bar{R} t(\bar{R}) + a_9 \bar{R} t(\bar{R}) + a_6 [t(\bar{R})]^2 \right\}$$

First, note that:

$$a_2 r + a_5 r^2 + a_7 r \bar{R} - \left\{ a_2 \bar{R} + a_5 \bar{R}^2 + a_7 \bar{R}^2 \right\} \\ = - \frac{\delta(r - \bar{R})}{(\beta + \gamma)(\beta + \gamma + \delta)} \left\{ 2(\beta + \gamma)[(\beta + \delta)A - \gamma \bar{A}] - \delta\gamma(r + \bar{R}) - 2\beta(\beta + \gamma + \delta)\bar{R} \right\} \\ \geq - \frac{2\delta(\beta + \gamma)(r - \bar{R})}{(\beta + \gamma)(\beta + \gamma + \delta)} \left\{ (\beta + \delta)(A - \bar{R}) - \gamma \bar{A} \right\} \geq 0$$

Thus, to prove that deviation is profitable it suffices to show that:

$$a_3 t^*(\bar{R}) + a_8 \bar{R} t^*(\bar{R}) + a_9 r t^*(\bar{R}) + a_6 [t^*(\bar{R})]^2 - \left\{ a_3 t(\bar{R}) + a_8 \bar{R} t(\bar{R}) + a_9 \bar{R} t(\bar{R}) + a_6 [t(\bar{R})]^2 \right\} \\ \geq \left(a_3 + (a_8 + a_9)\bar{R} \right) (t^*(\bar{R}) - t(\bar{R})) + a_6 \left\{ [t^*(\bar{R})]^2 - [t(\bar{R})]^2 \right\} \\ = \frac{\gamma}{(\beta + \gamma + \delta)^2} \left\{ [(\beta + \delta)(A - \bar{R}) - \gamma \bar{A}] (t^*(\bar{R}) - t(\bar{R})) - \frac{(\beta + \delta)(\beta + 2\gamma + \delta)}{2} \left([t^*(\bar{R})]^2 - [t(\bar{R})]^2 \right) \right\} > 0$$

where the last inequality follows from the fact $t^*(R)$ is the unique maximizer of

$$\frac{\gamma}{(\beta + \gamma + \delta)^2} \left\{ [(\beta + \delta)(A - R) - \gamma \bar{A}] t - \frac{(\beta + \delta)(\beta + 2\gamma + \delta)}{2} t^2 \right\}. \quad Q.E.D.$$

Proof of Proposition 1: We use Theorem 2 and the corollary from Mailath (1987) to prove this proposition. For this purpose we only need to check that the assumptions used in these results hold (these assumptions correspond to conditions (1) – (5) in Mailath (1987)).

(1) $V(R, r, t)$ is a polynomial and, hence, twice continuously differentiable in its arguments;

(2) Belief monotonicity: $\frac{\partial V}{\partial r} = a_2 + 2a_5 r + a_7 R + a_9 t < 0$

(3) Type monotonicity: $\frac{\partial^2 V}{\partial t \partial R} = a_8 < 0$ for all $(R, r, t) \in [\underline{R}, \bar{R}]^2 \times R_+$

Note that the function $V(R, r, t)$ is strictly concave in t $\left(\frac{\partial^2 V}{\partial t^2} = a_6 < 0 \text{ for all } (R, r, t) \in [\underline{R}, \bar{R}]^2 \times R_+ \right)$ and, hence, conditions of “strict” quasiconcavity (condition (4)) and boundedness (condition (5)) hold. *Q.E.D.*

Proof of Proposition 2: We know that $\frac{dt(R)}{dR} < 0$ and $\frac{\partial V(R, R, t(R))}{\partial r} < 0$. These two conditions

imply that $\frac{\partial V(R, R, t(R))}{\partial t} = l_0 + l_1 R + l_2 t(R) < 0$. Rearranging this equation yields

$$t(R) > \frac{(\beta + \delta)(A - R) - \gamma \bar{A}}{(\beta + \delta)(\beta + 2\gamma + \delta)} = t^*(R) \text{ for all } R \in [\underline{R}, \bar{R}]. \quad \text{Q.E.D.}$$

Appendix 2: Parameters definition

Parameter definitions for equation (20):

$$b_0 = e_x + \frac{A^2}{2\gamma} - \frac{A(A+\bar{A})}{(\beta+\gamma)} + \frac{\gamma(A+\bar{A})^2}{2(\beta+\gamma)^2}; b_1 = \frac{(2\beta+\gamma)A + \beta\bar{A}}{(\beta+\gamma)^2}; b_2 = \frac{\beta A - \gamma\bar{A}}{(\beta+\gamma)^2};$$

$$b_3 = \frac{\gamma[\beta A - \gamma\bar{A}]}{(\beta+\gamma)^2}; b_4 = -\frac{2\beta+\gamma}{2(\beta+\gamma)^2}; b_5 = \frac{\gamma}{2(\beta+\gamma)^2}; b_6 = -\frac{\beta\gamma[\beta+2\gamma]}{2(\beta+\gamma)^2};$$

$$b_7 = -\frac{\beta}{(\beta+\gamma)^2}; b_8 = -\frac{\beta\gamma}{(\beta+\gamma)^2}; b_9 = \frac{\gamma^2}{(\beta+\gamma)^2}.$$

Parameter definitions, equation (21)

$$a_0 = e_x + \frac{A^2}{2\gamma} - \frac{(A+\bar{A})((1+\phi)A - (1-\phi)\bar{A})}{2(\sigma+\gamma)}; a_1 = \frac{(\beta+\gamma+\sigma)A + \beta\bar{A}}{(\beta+\gamma)(\sigma+\gamma)}; a_2 = -\frac{\delta[\phi A - (1-\phi)\bar{A}]}{(\beta+\gamma)(\sigma+\gamma)};$$

$$a_3 = \frac{\gamma[\phi A - (1-\phi)\bar{A}]}{(\sigma+\gamma)}; a_4 = -\frac{2\beta+\gamma}{2(\beta+\gamma)^2}; a_5 = \frac{(1-\phi)\delta^2}{2(\beta+\gamma)^2(\sigma+\gamma)}; a_6 = -\frac{\gamma\phi(2-\phi)}{2};$$

$$a_7 = \frac{\beta\delta}{(\beta+\gamma)^2(\sigma+\gamma)}; a_8 = -\frac{\beta(1-\phi)}{(\beta+\gamma)}; a_9 = -\frac{(1-\phi)^2\delta}{(\beta+\gamma)}.$$

Parameter definitions, equation (30)

$$c_0 = e_x + \frac{A^2}{2\gamma} + \frac{\beta}{d^2} [(\beta+\delta)A - \gamma\bar{A}]^2 - \frac{\beta\gamma}{2d^2} [(2\beta+\delta)A + \beta\bar{A}][2(\beta+\gamma+\delta)A - \gamma\bar{A}];$$

$$c_1 = \frac{(2\beta+\delta)A + \beta\bar{A}}{d}; c_2 = -\frac{\beta\delta[(\beta+\delta)A - \gamma\bar{A}]}{d^2}; c_3 = \frac{\gamma\delta[(\beta+\delta)A - \gamma\bar{A}]}{d^2};$$

$$c_4 = -\frac{1}{(\beta+2\gamma)}; c_5 = \frac{\beta\gamma\delta^2}{2d^2(\beta+2\gamma)}; c_6 = -\frac{\gamma(\beta+\delta)(\beta+2\gamma+\delta)}{2d^2}; c_7 = \frac{\beta\delta}{d(\beta+2\gamma)};$$

$$c_8 = -\frac{\beta+\delta}{d}; c_9 = \frac{\beta(\beta+\delta)(\beta+2\gamma+\delta)}{d^2}.$$

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