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How to Design Trade Policy under Asymmetric Information?

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Abstract

Using a trade policy, government can shift profits from foreign firms to domestic firms. This paper will reexamine how asymmetric information can affect the equivalence of tariff and quota in a duopoly, where one domestic firm competes with one foreign firm. It can happen that the domestic firm has informational advantage against the government. Within this framework, the domestic firm has private information about own marginal cost as well as the foreign firm's. The domestic firm would exploit the advantage to draw a favorable policy from the government. When the government is misled, social welfare would decline. This paper will guide how the government can extract information from the domestic firm by offering a menu of tariff or quota. Previous studies showed that quota demands information more than tariff. With the principle of revealed information, the domestic firm chooses tariff (quota) if the marginal cost of foreign firm is low (high). The quota level will be high (low) if the marginal cost of domestic firm is high (low). To prevent misrepresentation, the domestic firm should be charged when quota is implemented. When the quota level is low, the domestic firm is charged additionally. This paper can contribute to the literature of trade policy and information.

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Ⅰ. Introduction

The theory of incentives has been extensively applied in many economic areas. However, its application to international trade has been limited. In fact, private information also matters for trade policy choice. Domestic firm has incentive to conceal information for drawing a favorable policy from the government. As shown by preceding studies, optimal trade policy is contingent on both demand parameter and cost structure. Thus, if domestic firm conceals information about cost structure, an asymmetric-information problem should arise. That is, domestic firm can exploit the private information in its best's interest. It was Brainard and Martimort (1992) that incorporated asymmetric information into the Brander-Spencer model. In their paper, private information of cost structure undermines the government's ability of committing to subsidy. As a result, the optimal subsidy should be lower under asymmetric information than under symmetric information. Using the same framework, Qiu (1994) showed that if the government offers domestic firm a menu of policies (export subsidy or a lump-sum tax) then the contract can extract cost information from domestic firm. With a uniform policy, the high-cost firm conceals own cost information.[1)]Meanwhile, Collie and Hviid (1993) addressed the signaling effect of export subsidy. That is, the government can use export subsidy to signal competency of domestic firm, internationally. With the effect, the optimal subsidy is larger under asymmetric information than under symmetric information. In addition, Collie and Hviid (1994) studied the case of a foreign monopolist, which is imperfectly informed about domestic market. That is, the demand parameter is unknown to the foreign monopolist while it is known to the domestic government. In this case, asymmetric information leads to a signaling game, which results in an excessive import tariff. Wright (1998) extended the Brander-Spencer model for two periods. In the first period, the output of domestic firm signals own marginal cost to the domestic government as well as foreign firm. Thus, domestic firm strategically chooses own output to extract a favorable policy from the domestic government in the second period. Using the Brander-Spence model, Kolev and Prusa (1999) found a pooling equilibrium in which foreign firm exports the same quantity regardless of cost structure. I examine how the government can design a trade policy with extracting cost information from domestic firm. The profit equivalence of tariff and quota plays important role in designing a trade policy. Regarding the equivalence, two papers deserve to be mentioned. Hwang and Mai (1988) studied that tariff and quota are equivalent in a duopoly model. Later, Matschke (2003) examined if the equivalence of tariff and quota is affected when firms have private information about demand parameter. She showed how a menu of contract can elicit the private information from firms. In her paper, trade policy is costly. So, a menu consists of tariff and price, or of quota and price. That is, the government sells domestic firm a protective policy. Bouet and Cassagnard (2013) claimed that selling a policy is unrealistic. Instead, they proposed a menu of tariff or quota, where the policies are not costly. They

1) Qiu (1994) showed that, under Bertrand competition, the expected welfare is larger under the uniform policy than under the separation-inducing policy. However, Okajima (2003) showed that no such separating equilibrium can exist.

showed that a menu of different policy instruments yields a separating equilibrium. In their paper, the domestic government proposed a menu of tariff or quota to the domestic firm. Then, the domestic firm reveals the information of demand parameter with choosing either policy. That is, if demand is low (high), the domestic firm chooses tariff (quota). I study how government can design a rent-extracting trade policy under asymmetric information. My study is close to Matschke (2003) and Bouet and Cassagnard (2013). However, the cost structure is different. Both studies focus on demand information while my study on cost information. In fact, Bouet and Cassanard included an analysis for cost information. In my paper, cost information is two-dimensional: two marginal costs. That is, the domestic firm privately know all the costs. Information naturally leaks within industry. Thus, it is not surprising that firms become aware of the rival's marginal cost. Sometimes, firms have stronger incentives to collect cost information of the rival more than government. My work underlies the crucial assumption that the domestic government never contact the foreign firm to extract information. Thus, in this paper, the domestic firm has greater informational rent than in Bouet and Cassagnard (2013). For a comparative study, I will consider two different cases. The first case is that the domestic firm knows own marginal cost only. The second case is that the domestic firm knows all the marginal costs. My paper emphasizes that quota demands information more than tariff. I will show that the government can extract information from the domestic firm using a menu of tariff or quota. In Bouet and Cassagnard (2013), tariff and quota are costless. In my paper, tariff is costless but quota is costly. Simply, the reason is that informational cost is larger for quota. Thus, the government chooses tariff when the domestic firm is presumed to have no information about the foreign rival. The optimal tariff rate is the same as that obtainable under uncertainty of marginal cost. The government proposes a menu of the tariff rate or a contingent quota upon the firm's report. Then, the optimal contract can be obtained in the following way. The government asks if the domestic firm knows the marginal cost of the foreign rival. If the domestic firm does not say 'Yes', then the tariff rate is set, and the game of contract ends. That is, the government gives up information extraction. In this case, the private information of the domestic firm does not matter. If the domestic firm says 'Yes', then the government commits to implementing quota, and the game of contract proceeds into the next stage. With the principal of information revelation, the domestic firm says 'Yes' only when the foreign firm is high-cost type. In the next stage, a quota is chosen contingently upon the self-reported marginal cost of the domestic firm. If the marginal cost is low (high), then the quota is low (high). The remainder of this paper will be structured as follows. Section II will discuss the case of complete information. In that section, the optimal tariff and quota will be derived. Section III will show that the derived optimal policies should be inefficient under asymmetric information. Section IV will be constituted of two sub-sections. The first sub-section will cover how the optimal contract can be designed when private information is one-dimensional: the domestic firm has private information of own marginal cost only. The second sub-section will cover the case of two-dimensional private information: the domestic firm knows the

foreign rival's marginal cost as well as own marginal cost. Section VI will provide concluding remarks.

Ⅱ. Complete Information

As mentioned, this section derives the optimal policies under complete information in a setting, where a domestic and a foreign firm compete for the domestic market. The domestic government wants to set a protective policy, which would shift profits from the foreign firm to the domestic firm. The profit shifting improves social welfare in the country. For the enactment of a policy, timing can be outlined as follows. In a first stage, the government commits to implementing a policy. In a second stage, both firms decide their output schedule given the government's commitment.

1. Optimal Tariff

Suppose that the government commits to tariff. Then tariff rate on imports can be optimized. Let denote a tariff rate. Subscript 1 and 2 denote the variables associated with domestic firm and foreign firm, respectively. An inverse demand is given as P=a-Q, where Q is an industrial quantity. Then the profit functions for both firms can be found as follows.

$$\pi_1 = \big(a - (q_1 + q_2)\big)q_1 - c_1 q_1, \tag{1}$$

$$\pi_2 = \big(a - (q_1 + q_2)\big)q_1 - (c_2 + t)q_2. \tag{2}$$

From (1) and (2), the Cournot-Nash equilibrium quantities are obtained as

$$q_1 = \frac{a-2c_1+c_2+t}{3} \text{ and } q_2 = \frac{a-2c_2+c_1-2t}{3}. \tag{3}$$

Domestic firm profit is obtained as

$$\pi_1(c_1, c_2) = \left[\frac{a-2c_1+c_2+t}{3}\right]^2. \tag{4}$$

Consumer surplus is obtained as

$$CS(t) = \frac{q_1^2}{2} = \frac{(21-c_1-c_2-t)^2}{18}. \tag{5}$$

Tariff revenue is obtained as

$$TR(t) = tq_2 = t\left[\frac{a-2c_2+c_1-2t}{3}\right]. \tag{6}$$

The government's objective is to maximize social welfare in the country. Social welfare can be defined as sum of domestic firm profit, consumer surplus, and tariff revenue.[2] That is, the function of social welfare is G(t)= π_1(t)+CS(t)+TR(t). Under complete information, the government solves the following maximization problem.

$$\begin{aligned} \text{Max}_t\ G(t) = &\left[\frac{a-2c_1+c_2+t}{3}\right]^2 \cdot \\ &+ \frac{(21-c_1-c_2-t)^2}{18} \\ &+ t\left[\frac{a-2c_2+c_1-2t}{3}\right]. \end{aligned} \tag{7}$$

Social welfare can be maximized at $t^* = \frac{a-c_2}{3}$. In note, the optimal tariff rate depends on c_2, the marginal cost of foreign firm. With the optimum t*, equilibrium quantities are determined as $q_1^* = \frac{2(2a-3c_1+c_2)}{9}$ and $q_2^* = \frac{(a+3c_1-4c_2)}{9}$.

2) In assumption, the government puts equal weights on domestic firm's profit, consumer surplus and tariff revenue.

Correspondingly, profits are determined as $\pi_1^* = [q_1^*]^2$ and $\pi_2^* = [q_2^*]^2$ for domestic firm and foreign firm, respectively.

2. Optimal Quota

Suppose that the government commits to imposing quota on imports. Let $\bar{q}$ denote a level of quota. Then the optimal level of quota can be found from the profit maximization as follows.

$$\pi_1 = (a - b(q_1 + \bar{q}) - c_1)q_1. \quad (8)$$

From the first order condition, the optimal quantity of domestic firm can be found as

$$q_1^* = \frac{a-c_1-\bar{q}}{2}. \quad (9)$$

Correspondingly, domestic firm profit, consumer surplus, and quota revenue can be found as $\pi_1(\bar{q}) = \left(\frac{a-c_1-\bar{q}}{2}\right)^2$, $CS(\bar{q}) = \frac{(a-c_1+\bar{q})^2}{8}$, and $QR(\bar{q}) = -\frac{3\bar{q}^2}{2} + \frac{\bar{q}(a+c_1-2c_2)}{2}$, respectively. In this case, social welfare can be defined as sum of domestic firm profit, consumer surplus, and quota revenue. Then the function of social welfare $G(\bar{q})$ is $G(\bar{q}) = \pi_1(\bar{q}) + CS(\bar{q}) + QR(\bar{q})$, and the government solves the following maximization problem.

$$\begin{aligned} Max_{\bar{q}}\ G(\bar{q}) = &\left(\frac{a-c_1-\bar{q}}{2}\right)^2 + \frac{(a-c_1+\bar{q})^2}{8} \\ &- \frac{3q^2}{2} + \frac{q(a+c_1-2c_2)}{2}. \end{aligned} \quad (10)$$

From the first order condition, the optimal level of quota can be found as

$$\bar{q}^* = \frac{a-4c_2+3c_1}{9}. \quad (11)$$

Correspondingly, the domestic firm output and domestic firm profit are found as

$$\begin{aligned} q_1^* = \frac{2(2a-3c_1+c_2)}{9} \text{ and } \pi_1 = (q_1^*)^2 \\ = \left(\frac{2(2a-3c_1+c_2)}{9}\right)^2. \end{aligned} \quad (12)$$

Meanwhile, the foreign firm obtains its profit as much as

$$\pi_2 = (\bar{q})^2 = \left(\frac{a-4c_2+3c_1}{9}\right)^2. \quad (13)$$

As Hwang and Mai (1985) and Matschke (2003) showed, the optimal levels of tariff and quota are profit-equivalent under complete information. Pointedly, the optimal tariff rate depends only on c_2 while the optimal quota level depends on both c_1 and c_2. If cost information is private, the informational rent should be larger when quota is implemented than when tariff is implemented.

3. Uncertainty

Suppose that the marginal costs are unknown. That is, cost information is never revealed. In this case, the government cannot extract cost information at any rate. Thus, no informational problem arises. Assume that the demand parameter is known publicly. In contrast, the marginal costs c_i $(i = 1,2)$ are unknown. For expositional simplicity, consider that marginal cost takes two values such as 'low' and 'high'. Let C_i denote the sets of values. Then, $c_i \in C_i = \{c_{iL}, c_{iH}\}$, where $0 < c_{iL} < c_{iH}$. A continuum of values

can be considered, however the result will not change qualitatively. Assume that the probability distribution is known: $P(c = c_{iH}) = \theta_i$ and $P(c = c_{iL}) = 1 - \theta_i$, where $0 < \theta_i < 1$. Under uncertainty, the government's problem is to maximize the expected social welfare. For each policy, the optimal levels are obtained as follows.

1) Optimal Tariff

$$t_\theta = \frac{a-\bar{c}_2}{3}, \quad \text{where } \bar{c}_2 = \theta_2 c_{2L} + (1-\theta_2)c_{2H}. \tag{14}$$

Note that the optimal tariff rate depends only on c_2, the marginal cost of foreign firm.

2) Optimal Quota

$$q_\theta = \frac{a-4\bar{c}_2+3\bar{c}_1}{9}, \quad \text{where } \bar{c}_1 = \theta_1 c_{1L} + (1-\theta_1)c_{1H}, \quad \text{and } \bar{c}_2 = \theta_2 c_{2L} + (1-\theta_2)c_{2H}. \tag{15}$$

Note that the optimal level of quota depends on both marginal costs, c_1 and c_2. If cost information is private, information rent is larger for quota. That is, the domestic firm has an incentive to under-report own marginal cost in its best interest. The low-cost type would truthfully report own marginal cost.

Ⅲ. Asymmetric Information

Suppose that information is asymmetric between the domestic firm and the government. That is, the domestic firm privately holds cost information. Thus, the domestic firm is an 'informed party' while the government is an 'uninformed party'. The government needs information to set an ex post efficient policy. However, the domestic firm would not give up its information rent. This section shows how a contract can be designed to extract information from the domestic firm. For the moment, assume that the government never attempts to elicit information from the foreign firm. In this paper, two different cases can be considered for private information. First, the domestic firm privately knows own marginal cost only. Second, the domestic firm privately knows both marginal costs: for own and the foreign rival. The second case will be analyzed in a later subsection.

1. Case 1

In this case, the domestic firm has private information of own marginal cost only. The government can acknowledge marginal cost c_1 only if the domestic firm reports truthfully. However, the government cannot acknowledge marginal cost c_2. In the literature of hidden information, the informed party holds private information entirely. In my study, information is two-dimensional. The first case represents that the informed party, the domestic firm, does not have all the information. It means that, despite its truthful report, information remains incomplete. That is, information of the foreign marginal cost is not revealed. In this case, the government expect it given the probability distribution. In this situation, the government still can screen domestic firm type. As shown already, the optimal levels of tariff and quota are $t^* = \frac{a-c_2}{3}$ and $\bar{q}^* = \frac{a-4c_2+3c_1}{9}$, respectively. With expectation, the optimal tariff rate is taken as $t_\theta = \frac{a-\bar{c}_2}{3}$,

where $\bar{c}_2 = \theta_2 c_{2L} + (1-\theta_2)c_{2H}$. Similarly, the optimal quota is taken as $\bar{q}_\theta = \frac{a-4\bar{c}_2+3c_1}{9}$. Unlike the optimal tariff rate, the optimal quota is also contingent on c_1. That is, depending on c_2, the optimal quota can take a value of either $\bar{q}_L = \frac{a-4\bar{c}_2+3c_{1L}}{9}$ or $\bar{q}_H = \frac{a-4\bar{c}_2+3c_{1H}}{9}$. The domestic firm has an incentive to under-report own marginal cost if its report is not verified. Thus, the government represses the firm's willingness of misrepresenting. One way is to charge the domestic firm whenever it under-reports own marginal cost. That is, if c_{1L} is claimed, the domestic firm is charged regardless of its true marginal cost. Then, it would lead to the situation that the high-cost type cannot mimic the low-cost type. That is, the government can offer the domestic firm a contract: a menu of tariff or quota. The optimal tariff rate is irrelevant of c_1. Thus, the domestic firm has no informational rent when tariff is implemented. However, the optimal quota is contingent on c_1. Thus, the domestic firm has informational rent when quota is implemented. Without verification, the domestic firm is willing to under-report own marginal cost. Thus, the domestic firm is requested to transfer out of its surplus in lump sum manner when quota is implemented. In fact, over-reporting never happens as long as the domestic firm is rational. So, the government aims to prevent the high-cost type from under-reporting. For prevention, the government can find a feasible set of x. That is, the low-cost type still has a surplus after x is subtracted. However, the high-cost type has no surplus. Thus, it cannot mimic the low-cost type. As a result, the high-cost type firm gives up under-reporting if x is charged. Then the optimal contract can be characterized as $\{t_\theta, (\bar{q}(\hat{c}_1), x)\}$, where $\hat{c}_1$ is the report of domestic firm and x is the charge. That is, if the domestic firm reports own marginal cost to the government, then quota is committed and, in sequence, a level of quota is determined with the report. In return, the domestic firm is obliged to redistribute x for quota revenue. If the domestic firm declines reporting, then the government commits to tariff in presuming that $c_1 = c_{1H}$. So, the government gives up information extraction and decides the optimal tariff rate t_θ on imports. In the literature of bilateral contracts, participation constraint plays important role. That is, the informed party can decline to participate in the game of 'contract' if the offer does not guarantee at least level of utility: a reservation utility. However, in my paper, participation constraint is not binding because it is involuntary. Implicatively, the domestic firm always prefers any protective policy to no protective policy. Participation constraint is equivalent as the 'break-even' condition: $\pi_1 \geq 0$. The first-order condition automatically satisfies the 'break-even' condition. Thus, in this paper, only incentive-compatible conditions are binding. Thus, the optimal contract is a solution to the following maximization problem.

$$\begin{aligned} &\mathrm{Max}_q\ \theta_1[G(q_L, c_{1L})] \\ &+ (1-\theta_1)[G(q_H, c_{1H})], \text{ subject to} \\ &\text{(i)}\ \ \pi_1(c_{1L}, \bar{c}_2, q_L) \geq \pi_1(c_{1L}, \bar{c}_2, q_H), \\ &\text{(ii)}\ \ \pi_1(c_{1H}, \bar{c}_2, q_H) \geq \pi_1(c_{1H}, \bar{c}_2, q_L). \end{aligned} \tag{16}$$

Constraints (i) and (ii) are incentive-compatible.

Lemma 1: Constraint (ii) is impossible.

It is apparent. There are two levels of quota such as high quota $\bar{q}_H$ and low quota

$\bar{q}_L$. In this paper, trade policy itself never affects marginal cost. Thus, without any charge, the high-cost type should earn greater profit from the low quota than from the high quota. So, the domestic firm has an incentive to claim that own marginal cost is c_{1L} although $c_1=c_{1H}$. Without verification, the government sets the low quota in accordance with the claim. That is, without any charge, the domestic firm is always better off with under-reporting. Thus, the contract cannot prevent the domestic firm from under-reporting. In contrast, the low-cost type never over-reports its marginal cost. Thus, the contract cannot screen cost type of domestic firm. Thus, the government charges x to make impossible that the high-cost type mimics the low-cost type. Otherwise, the contract is not truthfully implementable. Thus, constraints (i) and (ii) should be revised as follows.

$$\text{(i)'}\ \ \pi_1(c_{1L},\bar{c}_2,\bar{q}_L)-x\geq\pi_1(c_{1L},\bar{c}_2,\bar{q}_H), \quad (17)$$

$$\text{(ii)'}\ \ \pi_1(c_{1H},\bar{c}_2,\bar{q}_H)\geq\pi_1(c_{1H},\bar{c}_2,\bar{q}_L)-x. \quad (18)$$

$$\text{Remark: } \frac{\partial\pi_1(\cdot)}{\partial c_1}<0 \quad \text{and} \quad \frac{\partial^2\pi_1(\cdot)}{\partial c_1^2}>0.$$

$$\text{Thus, } \pi_1(c_{1L},\bar{c}_2,\bar{q}_L)-\pi_1(c_{1L},\bar{c}_2,\bar{q}_H) > \pi_1(c_{1H},\bar{c}_2,\bar{q}_L)-\pi_1(c_{1H},\bar{c}_2,\bar{q}_H).$$

That is, there exists an interval for x*, which represents the feasibility. Explicitly, the interval is as follows.

$$\pi_1(c_{1H},\bar{c}_2,\bar{q}_L)-\pi_1(c_{1H},\bar{c}_2,\bar{q}_H)\leq x^* \leq \pi_1(c_{1L},\bar{c}_2,\bar{q}_L)-\pi_1(c_{1L},\bar{c}_2,\bar{q}_H). \quad (19)$$

With a charge x*, the menu of contracts such as $[(c_{1H},t_\theta,0),(c_{1L},\bar{q}_L,x^*)]$ is truthfully implementable. Then, the high-cost (c_{1H}) type will give up reporting cost information, and the government implements tariff (t_θ). In this case, there is no charge (x*=0). The low-cost (c_{1L}) type will report truthfully own marginal cost, and the government implements the low quota ($\bar{q}_L$). Instead, the low-cost type is charged x*. My result goes along with Matschke (2003). That is, it supports that any protective policy needs to accompany a charge. In her paper, the government sells the domestic firm a protective policy. In my paper, the government does not sell it. Instead, the domestic firm is requested to transfer a fixed amount for quota revenue. It makes sense because the domestic firm benefits from the policy. As the quota level is lower, the benefit is greater. Thus, part of the surplus can be redistributed. Then, social welfare improves through screening firm types. In contrast, if the domestic firm declines to report cost information, tariff is implemented with no charge. The high-cost type can earn higher profit from tariff rather than from quota. It will be proved in a later section.

2. Case 2

In this case, the domestic firm has larger informational advantage. Suppose that the domestic firm has private information about both marginal costs, c_1 and c_2. Information leaks within industry. Thus, a firm becomes aware of its rival's cost structure. In assumption, the government never attempts to extract information directly from the foreign firm. Thus, whether the foreign firm has private information or not does not matter in this analysis. If the government does not take into account the possibility that the domestic firm privately knows c_2, then the optimal contract is equivalent as that in Section III.1. That is, the optimal levels of

tariff and quota are the same as in the preceding section. If the government knows that the domestic firm privately knows c_2 as well as c_1, then the game of 'contract' becomes different. Most of all, the government should recognize whether or not the domestic firm has private information of c_2. Under complete information, the optimal tariff and the optimal quota were derived as $t^* = \frac{a-c_2}{3}$ and $\bar{q} = \frac{a-4c_2+3c_1}{9}$, respectively. It is noteworthy that private information of c_2 affects not only the optimal quota but also the optimal tariff. Thus, it is harder to design a contract that extracts information from the domestic firm. Unlike the optimal tariff, the optimal quota are contingent on both c_1 and c_2. Thus, the domestic firm has incentive to under-report its marginal cost. That is, the domestic firm would claim that its marginal cost is low although it is actually high. In contrast, the domestic firm would report that the marginal cost of foreign firm is high although it is actually low. In this situation, the government can design a contract to screen cost type of the firm. Let $\hat{c}_1$ and $\hat{c}_2$ denote the reported marginal costs for the domestic firm and the foreign firm, respectively. Then, the government offers a menu of tariff or quota, $\{t_\theta, \bar{q}(\hat{c}_1, \hat{c}_2)\}$, to the domestic firm. Participation is voluntary. However, participation constraint is not binding here as explained already. Consider incentive-compatible constraints. Remind that the optimal tariff is $t = \frac{a-c_2}{3}$. The optimal tariff is contingent on c_2. Thus, the domestic firm has an incentive to under-report c_2 to the government. That is, the domestic firm exaggerates competency of foreign firm. Remind that the optimal quota is $\bar{q} = \frac{a-4c_2+3c_1}{9}$. The two marginal costs interact. There are four cases: (c_{1L}, c_{2L}), (c_{1L}, c_{2H}), (c_{1H}, c_{2L}) and (c_{1H}, c_{2H}). In the case of (c_{1L}, c_{2H}), the domestic firm has no incentives to distort information of the costs. In the case of (c_{1H}, c_{2L}), the domestic firm has incentives to distort information of the costs. For the two cases, (c_{1L}, c_{2L}) and (c_{1H}, c_{2H}), the domestic firm has an incentive to distort information of either marginal cost c_1 or c_2. To elicit information from the domestic firm, a simple contract can be proposed. First, the government asks whether or not the domestic firm privately knows the marginal cost of the foreign firm. If the domestic firm does not say 'Yes', then the government gives up collection of information and commits to implementing the tariff. That is, the tariff is set as t_θ, and the game of 'contract' ends. If the domestic firm says 'Yes', then the game proceeds to next stage. In this case, the government commits to implanting quota. Depending on report of the domestic firm, either the low quota or the high quota can be implemented.

Proposition 1: If the domestic firm privately knows that the foreign firm has low marginal cost (c_2=c_{2L}), the domestic firm prefers tariff to quota as long as the principle of revealed information holds.

Proof: There are two cases such as (c_{1L}, c_{2L}) and (c_{1H}, c_{2L}). Consider the first case, (c_{1L}, c_{2L}). Since the optimal tariff and quota are profit-equivalent, the domestic firm should earn the same profit from implementation of either tariff or quota. That is, $\pi_1(c_{1L}, c_{2L}, q_\theta) = \pi_1(c_{1L}, c_{2L}, t_\theta)$, where $q_\theta = \frac{a-4\bar{c}_2+3\bar{c}_1}{9}$ and $t_\theta = \frac{a-\bar{c}_2}{3}$. When the domestic firm truthfully reports marginal costs, the optimal quota is $q_{LL} = q(\hat{c}_{1L}, \hat{c}_{2L}) = \frac{a-4\hat{c}_{2L}+3\hat{c}_{1L}}{9}$. Then q_θ and q_{LL} can be compared by calculating $q_\theta - q_{LL}$. Since $\bar{c}_2 - \hat{c}_{2L} = \bar{c}_1 - \hat{c}_{1L} > 0$, it is

apparent that $q_\theta - q_{LL} = \frac{-4(\bar{c}_2-\hat{c}_{2L})+3(\bar{c}_1-\hat{c}_{1L})}{9} < 0$. That is, $q_\theta < q_{LL}$. Therefore, $\pi_1(c_{1L}, c_{2L}, q_{LL}) < \pi_1(c_{1L}, c_{2L}, q_\theta) = \pi_1(c_{1L}, c_{2L}, t_\theta)$. In this case, the domestic firm should prefer tariff t_θ to quota q_{LL}. Consider the second case, (c_{1H}, c_{2L}). When the domestic firm truthfully reports marginal costs, the optimal quota is $q_{HL} = q(\hat{c}_{1H}, \hat{c}_{2L}) = \frac{a-4\hat{c}_{2L}+3\hat{c}_{1H}}{9}$. Then q_θ and q_{HL} can be compared by calculating $q_\theta - q_{HL}$. Since $|\bar{c}_2 - \hat{c}_{2L}| = |\bar{c}_1 - \hat{c}_{1H}|$ and $\bar{c}_1 - \hat{c}_{1H} < 0$, it is apparent that $q_\theta - q_{HL} = \frac{-4(\bar{c}_2-\hat{c}_{2L})+3(\bar{c}_1-\hat{c}_{1H})}{9} < 0$. That is, $q_\theta < q_{HL}$. Therefore, $\pi_1(c_{1H}, c_{2L}, q_{HL}) < \pi_1(c_{1L}, c_{2L}, q_\theta) = \pi_1(c_{1H}, c_{2L}, t_\theta)$. In this case, the domestic firm should prefer tariff t_θ to quota q_{HL}.

Suppose an incentive-compatible contract. The domestic firm is obliged to transfer a fixed amount for quota revenue when quota is implemented. According to Lemma 1, the domestic firm has an incentive to over-report c_2 for low quota. Then, the size of the lump-sum transfer affects the willingness of over-reporting c_2. If it is sufficiently large, the domestic firm would prefer tariff t_θ to the low quota with over-reporting c_2. That is, quota can be truthfully implemented only if x is charged. Thus, the optimal contract should satisfy the following constraints.

$$\text{i)}\ \pi_1(c_{1H}, c_{2L}, q(\hat{c}_{2H})) - x \le \pi_1(t_\theta), \quad (20)$$

$$\text{ii)}\ \pi_1(c_{1L}, c_{2L}, q(\hat{c}_{2L})) - x \le \pi_1(t_\theta). \quad (21)$$

Thus, the two constraints imply that $x^* \ge \max\{\pi_1(c_{1L}, c_{2L}, q(\hat{c}_{2L})) - \pi_1(t_\theta), \pi_1(c_{1H}, c_{2L}, q(\hat{c}_{2H})) - \pi_1(t_\theta)\}$. Since $\pi_1(c_{1L}, c_{2L}, q(\hat{c}_{2L})) > \pi_1(c_{1H}, c_{2L}, q(\hat{c}_{2H}))$, the feasible set of x is $x^* \ge \pi_1(c_{1L}, c_{2L}, q(\hat{c}_{2L})) - \pi_1(t_\theta)$.

That is, for truthful implementation of quota, the domestic firm should be charged as at least as much as x*.

Lemma 2: If $c_1 = c_{1L}$ and $c_2 = c_{2H}$, the domestic firm has no incentive to misrepresent.

Proof: Suppose that the domestic firm truthfully reports. Then, the optimal quota is $q_{LH} = q(c_{1L}, c_{2H}) = \frac{a-4c_{2H}+3c_{1L}}{9}$. As derived, $q_\theta = \frac{a-4\bar{c}_2+3\bar{c}_1}{9}$. To compare q_θ and q_{HL}, the difference can be calculated as $q_\theta - q_{LH} = \frac{-4(\bar{c}_2-c_{2H})+3(\bar{c}_1-c_{1L})}{9}$. Since $|\bar{c}_2 - c_{2H}| = |\bar{c}_1 - c_{1L}|$ and $\bar{c}_2 - c_{2H} < 0$, the difference is greater than 0: $q_\theta - q_{LH} > 0$. Thus, $q_\theta > q_{LH}$. Therefore, $\pi_1(c_{1L}, c_{2H}, q_{LH}) > \pi_1(c_{1L}, c_{2H}, t_\theta)$. In this case, the domestic firm gains nothing from misrepresentation.

If an incentive-compatible contract is offered by the government, the domestic firm should prefer tariff to quota when $c_2 = c_{2L}$. In the case of (c_{1H}, c_{2H}), the domestic firm has no incentive to over-report c_2 but still has an incentive to under-report c_1. When the domestic firm truthfully reports marginal costs, the optimal quota is chosen as $q_{HH} = q(\hat{c}_{1H}, \hat{c}_{2H}) = \frac{a-4\hat{c}_{2H}+3\hat{c}_{1H}}{9}$. Then q_θ and q_{HH} can be compared by computing $q_\theta - q_{HH}$. Since $|\bar{c}_2 - \hat{c}_{2H}| = |\bar{c}_1 - \hat{c}_{1H}|$ and $\bar{c}_2 - \hat{c}_{2H} = \bar{c}_1 - \hat{c}_{1H} < 0$, it is apparent that $q_\theta - q_{HH} > 0$. That is, $q_\theta > q_{HH}$. Therefore, $\pi_1(c_{1H}, c_{2H}, q_{HH}) < \pi_1(c_{1H}, c_{2H}, t_\theta)$. By under-reporting c_1, the domestic firm would earn $\pi_1(c_{1H}, c_{2H}, q_{LH})$ instead of $\pi_1(c_{1H}, c_{2H}, q_{HH})$. Thus, the government should repress the willingness of under-reporting. That is, it needs another charge y whenever c_{1L} is

reported. Then, the optimal contract is a solution to the following optimization problem.

$$\begin{aligned}&\text{Max}_{(q,y)}\ \theta_1[G(\cdot)] + (1-\theta_1)[G(\cdot)], \\ &\text{subject to}\end{aligned} \tag{23}$$

(i) $\pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1H})\right) - x^* \geq \pi_1(t_\theta)$.

(ii) $\pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1L})\right) - x^* - y \geq \pi_1(t_\theta)$.

(iii) $\pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1H})\right) - x^* \geq \pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1L})\right) - x^* - y$.

(iv) $\pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1L})\right) - x^* - y \geq \pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1H})\right) - x^*$.

Lemma 3: Constraint (ii) is redundant. If constraints (i) and (iv) hold, then constraint (ii) is automatically satisfied. That is,

$$\begin{aligned}&\pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1L})\right) - x^* - y \\ &\geq \pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1H})\right) - x^* \\ &\geq \pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1H})\right) - x^* \geq \pi_1(t_\theta)\end{aligned}$$

For a quota to be implementable, the lower bound of x^* is

$$x^* \geq \pi_1\left(c_{1L}, c_{2L}, q(\hat{c}_{2L})\right) - \pi_1(t_\theta). \tag{24}$$

In addition, there is another charge y. That is, when a quota is chosen, x is charged. In proceeding, if the quota is low, y is charged additionally. Then, the feasible set for y^* can be found as

$$\begin{aligned}&\pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1L})\right) - \pi_1\left(c_{1H}, c_{2H}, q(\hat{c}_{1H})\right) \leq y^* \\ &\leq \pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1L})\right) - \pi_1\left(c_{1L}, c_{2H}, q(\hat{c}_{1H})\right).\end{aligned} \tag{25}$$

In summary, if the domestic firm has private information about the marginal costs, then the government offers the domestic firm a contract such as $[(q_L, x^*, y^*), (q_H, x^*, 0), (t_\theta, 0, 0)]$, which is a menu of policy instruments. The scheme can extract information of c_2 from the domestic firm because the level of c_2 determines the optimal levels of tariff and quota. Meanwhile, c_1 affects the optimal quota only. If c_2 is low, then the domestic firm prefers tariff to quota regardless of c_1. In this case, the scheme cannot elicit the information of c_1 because the domestic firm gives up implementation of quota. That is, the domestic firm conceals the information of c_2 by accepting tariff. Consequentially, the information of c_1 is also concealed. If the policy of quota is not costly, then the domestic firm would over-report c_2 for the low quota. However, the policy of quota is costly: a lump-sum transfer x^* is charged. With the charge, the domestic firm cannot benefit from quota when c_2 is low. In fact, the domestic firm benefits more from concealing the information that c_2 is low. Despite the charge, the domestic firm benefits from quota if c_2 is high. In this case, the domestic firm benefits more from revealing the information that c_2 is high. Thus, the domestic firm helps the government to resolve the asymmetric information problem and to implement quota. In the next stage, c_1 determines the optimal level of quota. That is, if it is low (high), then the quota is low (high). So, the domestic firm has incentive to under-report own marginal cost without a charge. Thus, for truthful implementation, the government should impose another charge on the domestic firm in case that the quota is low. In equilibrium, the government sets low (high) quota on imports if the domestic firm is low-cost (high-cost) type. In case of the low quota, the domestic firm is additionally charged y^*. In case that the domestic firm has private information about the marginal costs, the charge is larger. Simply, the reason is that the information rent is larger. That is, the

domestic firm has stronger incentive to distort cost information. Thus, the government should charge the domestic firm more if the quota is low. Then, the high-cost type cannot mimic the low-cost type because of the charges.

Ⅳ. Conclusion

This paper has explored how the government can extract cost information from the domestic firm for implementation of trade policy. Unlike previous studies, this paper has considered the case that the domestic firm has cost information of the foreign firm. That is, the domestic firm has the larger informational rent, and has incentives to distort the information. This paper proposes a truthful contract. The government offers the domestic firm a menu of the instruments, tariff or quota. As shown, the optimal quota is contingent on both marginal costs. Accordingly, when quota is implemented, the domestic firm has larger information advantage. So, the government should prevent the domestic firm from exploiting the informational advantage. That is, the domestic firm is charged when quota is implemented. If the marginal cost of the foreign firm is low, the domestic firm would prefer tariff to quota. In that situation, the domestic firm never benefits from quota. If the marginal cost of the foreign firm is high, the domestic firm can benefit from quota. Thus, the domestic firm is willing to reveal the cost information to the government. As a result, quota is implemented. Next, the optimal quota is contingent on the marginal cost of the domestic firm. Within this framework, the domestic firm never over-reports own marginal cost. Instead, it would under-report the marginal cost for the low quota. Thus, the domestic firm should be charged additionally when the low quota is chosen. Otherwise, the domestic firm always under-reports its marginal cost. In contrast, the charge induces the domestic firm to truthfully reveal its marginal cost. This paper can be extended. So far, it has considered unilateral intervention. However, the government intervention can cause counteracting intervention by the foreign government. That is, unilateral intervention extends to bilateral intervention. Bilateral intervention would lead to a simpler result in a duopoly model than a Brander-Spencer model. Only, the marginal cost of the foreign firm will be reduced, however there will be no strategic interdependence. Then, the informational advantage of the domestic firm should be reduced. That is, when the foreign government commits to intervening, the commitment can signal to the domestic government that the domestic firm has no private information of the foreign firm. This paper highlights that quota demands information more than tariff. For extension, a different informational structure can be supposed. In fact, the government might have private information of policy design while firms do not. Most likely, social welfare should is lower in this case. It can be analyzed. So far, only two firms have been considered. Number of firms can be arbitrary, and information rent would be different across firms. Accordingly, the optimal contract can be designed. The missions are left for future researchers.

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