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Strategic Trade Policy under Asymmetric Information about Market Demand

by

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Abstract

This paper examines strategic trade policy with unilateral intervention under asymmetric information about market demand. In an international Cournot-duopoly, the choice of the domestic country's export subsidy signals the domestic country's private information to the foreign firm. It is shown that this signalling effect weakens the well-known commitment effect of positive export subsidies. The optimal export subsidy under asymmetric information is smaller than the optimal export subsidy with perfect information. If the range of the uncertain market demand is sufficiently large, then the optimal export subsidy is negative and the domestic country's welfare may be smaller than the foreign country's welfare.

Key words: Strategic trade policy, asymmetric information, market demand.

JEL Classification: F13

1 Introduction

One of the most influential models of strategic trade is by Brander and Spencer (1985). An international Cournot-duopoly is incorporated into a "third market" model. Two firms, one of which is located in the home country and the other on in the foreign country, produce a homogeneous good for a third market. Brander and Spencer have shown that it is individually rational for the home country to adopt an export subsidy policy if the home firm competes with the foreign firm in quantities. In a Cournot-duopoly, the unilateral government intervention provides a strategic advantage, leading to rent shifting from the foreign firms to the home country. One of the major objections to strategic trade policy is that it presumes too much knowledge about market variables. The existence of informational asymmetries is both indisputable and important. So far however, the analysis of the effects of informational asymmetries on strategic trade policy is still in its infancy stages.

This paper considers a situation with asymmetric information about market demand in the third market. Asymmetric information arises very naturally when there is uncertainty about the true market demand and firms try to acquire additional information about the future market demand by doing market research. In such a situation, a firm has private information about the market demand and the use of the trade policy may be a signalling device about the private information.

To bring out the signalling effect most clearly, we analyze this situation in a very simple setting. For simplicity, it is assumed that the domestic country and its firm have private information about the market demand. Furthermore, we consider the case with unilateral intervention, namely that only the domestic country has the possibility to subsidize its firm. In a more realistic model, both firms would have the possibility to use export subsidies, but the qualitative signalling effect would be the same.

In our model, the domestic country's strategic trade policy has two effects on the domestic country's welfare. Firstly, an export subsidy to the domestic firm lowers the marginal cost of production and the domestic firm credibly commits itself to an aggressive behavior on the output market in the third country. In the perfect information model, this commitment effect induces rent shifting from the foreign country to the domestic country. Secondly, the strategic trade policy has, on the domestic country's welfare, an indirect effect consisting of a signalling effect on the foreign firm's expectation and of an expectation effect on the foreign firm's optimal behavior and hence the domestic country's welfare. With perfect information, it will be shown that the higher the market demand, the larger will be the optimal export subsidy of the domestic country to the domestic firm. Thus, when the domestic country and the domestic firm have private information about the future market demand, a larger export subsidy may lead the foreign firm to increase its expectations about the market demand. The higher the foreign country's expectation about the market demand, the larger will be the optimal output level on the third market. In a Cournot-duopoly with downward sloping reaction functions, this will lead the domestic country to decrease its output level which in turn will have a negative effect on the domestic country's welfare. Thus, the direct and indirect effect work in opposite directions. The direct effect leads the domestic country to set a positive export subsidy to create a strategic advantage on the third market. The indirect effect induces the domestic country to lower the optimal export subsidy (compared to the perfect information situation) in order to signal low market demand so that the foreign firm chooses a smaller output level. The domestic firm in turn chooses a larger output level on the third market and the domestic welfare increases. The signalling effect is greater, the larger the range of the uncertain market demand is. If this range is sufficiently large, the indirect effect is stronger than the direct effect so that the optimal export subsidy may be negative. If both firms have identical marginal costs, the domestic country may receive a smaller welfare than the foreign country, although the domestic country has private information about the market demand and can use the export subsidy to commit to itself an aggressive behavior on the output market.

The analysis of the effects of informational asymmetries is still in its early stages. To our knowledge, this is the first paper analyzing the effects of asymmetric information about market demand in a strategic trade model. Several recent papers have considered the effect of cost-based informational asymmetries. Collie and Hviid (1993) analyze the case in which the domestic country and the domestic firm know the domestic firm's marginal costs, the foreign country, however, does not. Qiu (1994) assumes that the domestic firm knows its own marginal costs, but neither the domestic country nor the foreign firm knows the true marginal costs of the domestic firm. And finally, Brainard and Martimort (1997) consider a situation in which both firms can observe the domestic firm's marginal costs and only the domestic country is uninformed. The model by Collie and Hviid is closest to our model, as they, too consider a signalling game in which the strategic trade policy serves as a signalling device about the true marginal costs of the domestic firm. In contrast to our model, the indirect (signalling plus expectation) effect strengthens the commitment effect so that, with asymmetric information about marginal costs, the optimal export subsidy is larger than the optimal export subsidy with perfect information. Similar to our model, the domestic country wants to lower the foreign firm's expectations about the domestic firm's marginal costs. In contrast to our model, however, this is achived by increasing the optimal export subsidy.

The observation that uncertainty about marginal costs and uncertainty about market demand leads to opposite effects is not new in economic literature. For example in the literature to be found on "information sharing in oligopoly", the different information structure reverses the incentives of sharing private information with the competitors, see for example Gal-Or (1986).

The paper is organized as follows. In Section 2, we present the basic model with perfect information situation as the benchmark case. In Section 3, we analyze the situation with asymmetric information about market demand and derive the results. Section 4 discusses extensions of the model and concludes with some implications for trade policy.

2 Perfect Information

The basic model follows Brander and Spencer (1985). An international Cournot-duopoly is incorporated into a "third market" model. Two firms, 1 and 2, who are located in the home country (country 1) and in the foreign country (country 2), produce a homogeneous good for a third market. The inverse demand function takes the form $p = a - x_1 - x_2$, where $a > 0$ is the market demand intercept, p is the price of the product, and x_i the output of firm i, $(i = 1, 2)$. The production of one unit output of firm i costs c_i, $(i = 1, 2)$. In order to have interior solutions, it is assumed that $a > 3c_i \geq 0$, $(i = 1, 2)$.

The game structure is as follows: at time $t = 0$, both firms and countries know all market variables. At time $t = 1$, the domestic country sets a subsidy level s per unit. At time $t = 2$, both firms observe the subsidy level and choose simultaneously their output levels x_i $(i = 1, 2)$ for the third market. And finally, at time $t = 3$, the payoffs are realized. A strategy for the domestic country is to set a subsidy level s in $t = 1$. A strategy for firms 1 and 2 is an output level x_1 and x_2 respectively dependent on the subsidy level s observed in $t = 1$.

The game is solved using the subgame perfect equilibrium concept by Selten (1975). Firm 1 receives a subsidy of s per unit of production. Hence, the expected payoffs are

$$\pi_1(s) = x_1(s)(a - x_1(s) - x_2(s) - c_1 + s) \quad (1)$$
$$\pi_2(s) = x_2(s)(a - x_1(s) - x_2(s) - c_2) \quad (2)$$

The firms are assumed to maximize the expected payoff. From the first order condition for an optimal choice of x_1 and x_2 follows

$$x_1(s) = \frac{1}{2}a - \frac{1}{2}c_1 + \frac{1}{2}s - \frac{1}{2}x_2(s) \ \ for x_2(s) \geq a - c_1 + s \quad (3)$$
$$x_2(s) = \frac{1}{2}a - \frac{1}{2}c_2 - \frac{1}{2}x_1(s) \ \ for x_1(s) \geq a - c_2 \quad (4)$$

Equations (3) and (4) form an equation system with two equations and two unknown variables. The solution is

$$x_1(s, a) = \frac{1}{3}(a - 2c_1 + c_2 + 2s) \quad (5)$$
$$x_2(s) = \frac{1}{3}(a - 2c_2 + c_1 - s), \quad (6)$$

for $c_1 - 0.5c_2 - 0.5a \leq s \leq a - 2c_2 + c_1$. Given this restriction, both output levels are non-negative. A positive subsidy level lowers the marginal costs of production for firm 1. Therefore it has a positive effect on the equilibrium production of firm 1. In a Cournot-model with downward sloping reaction functions, this has a negative effect on the equilibrium output of firm 2.

The domestic country anticipates the optimal behavior of firms 1 and 2. The domestic welfare is the producer surplus from export net of the export subsidy. Using equations (5) and (6) the domestic welfare is

$$W_1(s) = \frac{1}{32}(2a - 4c_1 + 2c_2)^2 - \frac{2}{9}\left(\frac{1}{4}a - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \quad (7)$$

for $c_1 - 0.5c_2 - 0.5a \leq s \leq a - 2c_2 + c_1$. The domestic country chooses the subsidy to maximize the domestic welfare given in equation (7). It is easy to see that the subsidy

$$s^p = \frac{1}{4}a - \frac{1}{2}c_1 + \frac{1}{4}c_2 \tag{8}$$

maximizes the domestic welfare. The solution (8) satisfies the restriction for s. As can be seen from equation (8), the higher the market demand, the larger the optimal export subsidy. The intuition for these results is as follows: with higher market demand, the domestic country wants to sell more output on the third market and therefore lowers the marginal cost of production of the domestic firm by choosing a larger export subsidy.

3 Asymmetric Information

In the following, we consider a situation with uncertainty about the market demand. It is assumed that with probability p market demand is low a_l and with probability $1 - p$ market demand is high a_h. To guarantee an interior solution, it is assumed that $a_h > a_l \geq 3c_i \geq 0$ with $i = 1, 2$ and $a_h \leq 2a_l - 2c_1 + c_2$. The game structure is as follows: at time $t = 0$, the domestic firm and the domestic country know the future market demand while the foreign firm and the foreign country know only the probability distribution of a. At time $t = 1$, the domestic country sets a subsidy level s per unit production. At time $t = 2$, both firms observe the subsidy level and choose simultaneously their output levels x_i $(i = 1, 2)$ for the third market. And finally, at time $t = 3$, the payoffs are realized. A strategy for the domestic country is a subsidy level s dependent on the private information a. A strategy for firm 1 is an output level x_1 dependent on the subsidy level s and the private information a. A strategy for firm 2 is an output level x_2 dependent on the subsidy level s.

The appropriate solution concept is a perfect Bayesian equilibrium combining the idea of subgame perfection, Bayesian equilibrium and Bayesian inference. At each point of time, the strategies form a Bayesian equilibrium for given expectations whereby the expectations follow Bayes rule. A perfect Bayesian equilibrium consists of strategies and expectations, such that the strategies are optimal given the expectations and the expectations are consistent with Bayes rule and the equilibrium strategies. Because of this circularity, a perfect Bayesian equilibrium cannot be determined backwards starting at the end of the game. Thus, we analyze first the optimal behavior in $t = 2$ and $t = 1$ for given expectations and then derive the optimal behavior and expectations so that they are consistent with each other.

3.1 Optimal Behavior in t=2

The optimal behavior in $t = 2$ depends on the expectations of firm 2 about the market demand. Since the domestic country knows the market demand, the foreign firm infers the market demand from the subsidy level set by the domestic country in $t = 1$. After having seen the subsidy level s, firm 2 believes with probability $q(s)$ that market demand is low a_l, and with probability $1 - q(s)$ that market demand is high a_h. For the moment we take firm 2's expectations as given and analyze them later. The expected payoffs are

$$\pi_1(a,s) = x_1(s,a)(a - x_1(s,a) - x_2(s) - c_1 + s) \qquad (a = a_l, a_h) \quad (9)$$

$$\pi_2(s) = x_2(s)(\bar{a}(s) - \bar{x}_1(s) - x_2(s) - c_2), \quad (10)$$

whereby $\bar{a}(s)$ denotes firm 2's expectation about the market demand, $\bar{a}(s) = q(s)a_l + (1 - q(s))a_h$, and $\bar{x}_1(s)$ denotes firm 2's expectation about firm 1's output decision, $\bar{x}_1(s) = q(s)x_1(s,a_l) + (1 - q(s))x_1(s,a_h)$ after having seen the subsidy s set by the domestic country in $t = 1$. From the first order condition for an optimal choice of x_1 and x_2 follows

$$x_1(a,s) = \frac{1}{2}a - \frac{1}{2}c_1 + \frac{1}{2}s - \frac{1}{2}x_2(s) \;\; for \;\; x_2(s) \geq a - c_1 + s, \quad (a = a_l, a_h) \quad (11)$$

$$x_2(s) = \frac{1}{2}\bar{a}(s) - \frac{1}{2}c_2 - \frac{1}{2}\bar{x}_1(s) \;\; for \;\; \bar{x}_1(s) \geq \bar{a}(s) - c_2 \quad (12)$$

Equations (11) and (12) form an equation system with three equations and three unknown variables. The solution is

$$x_1(a,s) = \frac{1}{6}(3a - 4c_1 + 2c_2 + 4s - \bar{a}(s)), \quad (a = a_l, a_h) \quad (13)$$

$$x_2(s) = \frac{1}{3}(\bar{a}(s) - 2c_2 + c_1 - s) \quad (14)$$

for $c_1 - 0.5c_2 + 0.5\,\bar{a}(s) - a_l \leq s \leq 2\,\bar{a}(s) - a_h - 2c_2 + c_1$. Given this restriction, both output levels are non-negative. Given the function $q(s)$ which represents firm 2's expectation about the market demand, equations (13) and (14) describe the optimal behavior of both firms at time $t = 2$.

As can be seen from equations (13) and (14), the strategic trade policy has a direct and an indirect effect on the optimal behavior of the firms. At first, a positive subsidy level lowers the marginal costs of production for firm 1. Hence, it has a positive effect on the equilibrium production of firm 1 and in a Cournot-duopoly with downward sloping reaction functions a negative effect on the equilibrium output of firm 2. Furthermore, the trade policy has an indirect effect on the firms optimal behavior because the export subsidy influences firm 2's expectation and the optimal behavior depends on firm 2's expectation about the market demand. Higher expectations of firm 2 about the market demand result in a higher output level of firm 2 and lower output level of firm 1.

3.2 Optimal Behavior in t=1

The domestic country anticipates the optimal behavior of both, the domestic and the foreign firm. The domestic welfare is the producer surplus from export net of the export subsidy. Using equations (13) and (14), the domestic country's optimization problem is

$$\begin{aligned} & \max_s W_1\left(a, s, \bar{a}\left(s\right)\right) \qquad\qquad (a = a_l, a_h) \qquad (15) \\ = \quad & \max_s \frac{1}{32}\left(3a - \bar{a}(s) - 4c_1 + 2c_2\right)^2 - \frac{2}{9}\left(\frac{3}{8}a - \frac{1}{8}\bar{a}(s) - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \end{aligned}$$

for $c_1 - 0.5c_2 + 0.5\,\bar{a}\left(s\right) - a_l \leq s \leq 2\,\bar{a}\left(s\right) - a_h - 2c_2 + c_1$. For fixed expectations $\bar{a}\left(s\right) = \bar{a}$, equation (15) describes a parabola which is opened downwards. The coordinates of the maximum can be directly taken from equation (15). The welfare function of the domestic country has the property that the increase of firm 2's expectation about the market demand will decrease the welfare, that is

$$\frac{\partial W_1\left(a, s, \bar{a}\right)}{\partial\,\bar{a}} = -\frac{1}{18}\left(3a - \bar{a} - 4c_1 + 2c_2 + s\right) < 0 \qquad (a = a_l, a_h) \qquad (16)$$

for $c_1 - 0.5c_2 + 0.5\,\bar{a}\left(s\right) - a_l \leq s \leq 2\,\bar{a}\left(s\right) - a_h - 2c_2 + c_1$. Hence, it is in the domestic country's interest to lower the foreign firm's expectation about the market demand.

3.3 Strategies and Expectation in Equilibrium

For given expectations $q(s)$, the optimal output levels of both firms are described by equations (13) and (14). The solution of the welfare maximization problem in (15) is the optimal export subsidy of the domestic country. In a Bayesian perfect equilibrium not only the strategies are a best response with respect to the expectations, but also the expectations are consistent with both the strategies and Bayes rule.

We denote with s_l and s_h respectively the domestic country's equilibrium export subsidy with private information a_l and a_h respectively. If in equilibrium the domestic country chooses independently of the private information the same strategic trade policy, that is $s_l = s_h$, then we have a pooling equilibrium. In a pooling equilibrium, the foreign firm infers nothing from observing the domestic country's equilibrium export subsidy. Thus the equilibrium expectations are $q(s_l) = q(s_h) = p$. For all export subsidies out off the equilibrium path, their are no restrictions on the foreign firm's expectations.

If in equilibrium the domestic country's optimal behavior is different for different private information, that is $s_l \neq s_h$, then we have a separating equilibrium. In a separating equilibrium, the foreign firm can infer the domestic country's private information from observing the domestic country's optimal choice. Hence, firm 2's equilibrium expectations are $q(s_l) = 1$ and $q(s_h) = 0$ and the expectations about the market demand are $\bar{a}(s_l) = a_l$ and $\bar{a}(s_h) = a_h$ respectively.

3.4 Separating equilibrium

A separating equilibrium consists of a strategy s_l, s_h with $s_l \neq s_h$ for the domestic country, a strategy $x_1(a, s)$, $(a = a_l, a_h)$ for the domestic firm, and a strategy $x_2(s)$ for the foreign firm, as well as expectations for the foreign firm $\bar{a}(s)$, with $\bar{a}(s_l) = a_l$ and $\bar{a}(s_h) = a_h$ such that the firms' optimal behavior at time $t = 2$ satisfies (13) and (14) and the domestic country's optimal behavior at time $t = 1$ satisfies

$$W_1(a_l, s_l, a_l) \geq W_1(a_l, s, \bar{a}(s)), \tag{17}$$

$$W_1(a_h, s_h, a_h) \geq W_1(a_h, s, \bar{a}(s)). \tag{18}$$

These two conditions state that given the private information a_l and a_h, the equilibrium subsidies s_l and s_h give the domestic country at least as much welfare as any other subsidy.

In the following, we show that the equilibrium conditions (17) and (18) imply the domestic country choosing the same export subsidy under asymmetric information as with perfect information when the market demand is high. When the market demand is low, the optimal export under asymmetric information is smaller than the optimal export subsidy with perfect information.

If there exists a separating equilibrium, the domestic country's optimal export subsidy is smaller than the optimal export subsidy with perfect information, with

$$\begin{aligned} s_h &= \frac{1}{4}a_h - \frac{1}{2}c_1 + \frac{1}{4}c_2 = s_h^p, && (19)\\ s_l &\leq \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} < s_l^p && (20)\end{aligned}$$

Consider first the domestic country's equilibrium export subsidy with the private information that the market demand is high. The export subsidy s_h maximizes the domestic country's welfare with $a = \bar{a} = a_h$ as can be seen from the welfare maximization problem (15), that is $W_1(a_h, s_h, a_h) > W_1(a_h, s, a_h)$ for all $s \neq s_h$. Suppose there exists a separating equilibrium with $\hat{s}_h \neq s_h$. Then by construction $W_1(a_h, s_h, a_h) > W_1(\hat{s}_h, a_h, a_h)$. With property (16) it would follow that $W_1(a_h, s_h, \bar{a}(s_h)) > W_1(a_h, s_h, a_h)$. Combining these two inequations gives $W_1(a_h, s_h, \bar{a}(s_h)) > W_1(a_h, \hat{s}_h, a_h)$ which would contradict the assumption that $\hat{s}_h$ is the equilibrium subsidy with private information a_h.

Consider now the domestic country's optimal subsidy with the private information that market demand is low. With $s = s_l$ and $\bar{a}(s_l) = a_l$ condition (18) becomes $W_1(a_h, s_h, a_h) \geq W_1(a_h, s_l, a_l)$. In Appendix A we show that this condition restricts s_l as follows: $s_l \leq s_{11}$ or $s_l \geq s_{12}$, whereby s_{11} and s_{12} are defined in Appendix A. In Appendix B we show that $s_{11} < s_l^p < s_{12}$, whereby s_l^p is equilibrium subsidy with perfect information, when the market demand is low. With $s = s_{lh} := 0.375a_l - 0.125a_h - 0.5c_1 + 0.25c_2$ condition (17) becomes $W_1(a_l, s_l, a_l) \geq W_1(a_l, s_{lh}, \bar{a}(s_{lh}))$. The subsidy s_{lh} maximizes the welfare with low market demand and high expectations. Since by property (16) $W_1(a_l, s_{lh}, a(s_{lh})) \geq W_1(a_l, s_{lh}, a_h)$, a necessary condition is $W_1(a_l, s_l, a_l) \geq W_1(a_l, s_{lh}, a_h)$. In Appendix C we show that this inequation contradicts with $s_l \geq s_{12}$ and is satisfied with $s_l = s_{11}$ for $a_h \leq \frac{16}{29}c_2 - \frac{32}{29}c_1 +$

$\frac{45}{29}a_l$. The expression on the right hand side in inequation (20) is s_{11}. The subsidies s_l and s_h satisfy the restriction of the firms' optimal behavior, as shown in Appendix D.

The intuition for this result is as follows. The choice of the strategic trade policy has two effects on the welfare function in (15). The direct effect is the well-known commitment effect which increases the domestic country's welfare. The indirect effect consists of the signalling effect on firm 2's expectations and the expectations effect on country 1's welfare. By property (16), the domestic country has an incentive to signal the foreign firm low market demand. With perfect information the higher the market demand, the larger the optimal export subsidy. Thus, under asymmetric information a larger export subsidy signals high market demand. It follows that the domestic country chooses a smaller export subsidy as under perfect information in order to signal low market demand and to increase its welfare. The signalling effect is stronger, the greater the difference is between the low and high market demand. If the high market demand is sufficiently large, the indirect effect is stronger than the commitment effect, and the optimal export subsidy s_l is negative.

The export subsidy s_l is negative if and only if the market demand in the good state is sufficiently large, that is

$$a_h > \frac{2-2\sqrt{2}}{3}c_1 - \frac{1-\sqrt{2}}{3}c_2 + \frac{2+\sqrt{2}}{3}a_l.$$

The proof is in Appendix E. A corollary of this result is that if both firms have the same marginal costs and the export subsidy is negative, the domestic country's welfare is smaller than the foreign country's welfare. This result follows immediately from the observation that in a Cournot-duopoly with identical firms, both firms realize the same profit. If the reaction function of one firm shifts outwards, this firm increases its profit, and when the reaction function shifts inwards this firm decreases its profit. Thus, if both, the domestic and the foreign firm have the same marginal costs as wll as a negative export subsidy, shifts the reaction function inwards.

Let $a = a_l$ and $c_1 = c_2$. Then the domestic country's welfare is smaller than the foreign country's welfare if and only if the market demand in the good state is sufficiently large, that is

$$a_h > \frac{2-2\sqrt{2}}{3}c_1 - \frac{1-\sqrt{2}}{3}c_2 + \frac{2+\sqrt{2}}{3}a_l.$$

At least, we state under which conditions there exists a separating equilibrium.

There exists a separating equilibrium if and only if

$$a_h \leq \frac{16}{29}c_2 - \frac{32}{29}c_1 + \frac{45}{29}a_l.$$

In the following, we show that there exists a separating equilibrium which satisfies equation (19) and inequation (20) with equality. Let firm 2 believe that the domestic country has the private information that the market demand is low if they observe an export subsidy which is smaller than the equilibrium export subsidy under private information a_l, that is $q(s) = 1$ and hence $\bar{a}(s) = a_l$ for all $s \leq s_l$. Otherwise firm 2 believes that market demand is high, that is $q(s) = 0$ and hence $a(s) = a_h$ for all $s > s_l$. Condition (18) then becomes $W_1(a_h, s_h, a_h) \geq W_1(a_h, s, a_h)$ for all $s > s_l$ and $W_1(a_h, s_h, a_h) \geq W_1(a_h, s, a_l)$ for all $s \leq s_l$. The first inequation is satisfied by construction of s_h and the second inequation is satisfied by the construction of s_l. Condition (17) becomes $W_1(a_l, s_l, a_l) \geq W_1(a_l, s, a_h)$ for all $s > s_l$ and $W_1(a_l, s_l, a_l) \geq W_1(a_l, s, a_l)$ for all $s \leq s_l$. The second inequation is fulfilled because of the parabolic functional form of W_1. The second inequation is fulfilled, because as shown in Appendix C, $W_1(a_l, s_l, a_l) \geq \max_s W_1(a_l, s, a_h)$ if $a_h \leq \frac{16}{29}c_2 - \frac{32}{29}c_1 + \frac{45}{29}a_l$.

3.5 Pooling equilibrium

A pooling equilibrium consists of a strategy s_{lh} with $s_{lh} = s_l = s_h$ for the domestic country, a strategy $x_1(a, s)$, $(a = a_l, a_h)$ for the domestic firm and a strategy $x_2(s)$ for the foreign firm as well as expectations $\bar{a}(s)$ with $\bar{a}(s_{lh}) = a_e \equiv pa_l + (1-p)a_h$ for the foreign firm such that the firms' behavior satisfies (17) and (18) and the domestic firm's behavior satisfies

$$W_1\left(a_l, s_{lh}, a_e\right) \geq W_1\left(a_l, s, \bar{a}\left(s\right)\right), \tag{21}$$

$$W_1\left(a_h, s_{lh}, a_e\right) \geq W_1\left(a_h, s, \bar{a}\left(s\right)\right). \tag{22}$$

There exists a continuum of pooling equilibria. All of them can be supported with firm 2's expectations $\bar{a}(s) = a_h$ for all $s \neq s_{lh}$. A necessary and sufficient condition for the equilibrium subsidy s_{lh} is $W_1(a_l, s_{lh}, a_e) \geq \max_s W_1(a_l, s, a_h)$

and $W_1(a_h, s_{lh}, a_e) \geq \max_s W_1(a_h, s, a_h)$. If the subsidy s_{lh} does not satisfy one of these conditions for some s', then country 1 deviates to the subsidy s' because $W_1(a_i, s_{lh}, a_e) < \max_s W_1(a_i, s', a_h) \leq W_1(a_i, s', \bar{a}(s'))$, $(i = l, h)$. If the subsidy s_{lh} satisfies both conditions, then it can be supported as a pooling equilibrium with $\bar{a}(s) = a_h$ for all $s \neq s_{lh}$.

Unfortunately, none of the existing refinement concepts eliminates all pooling equilibria because in both states of the world, the domestic country can get a higher payoff than the equilibrium payoff, if the foreign firm expects low market demand. Nevertheless, the pooling equilibria are implausible if one assumes passive conjectures (comp. Rasmusen, 1989), that is, if firm 2 receives no information, it has expectations $\bar{a}(s) = a_e$. Given these expectations, no pooling equilibrium can be supported.

4 Conclusions

In this paper, we consider a situation with private information about market demand, in which the strategic policy is a signalling device about private information. We have shown that the country with the private information may have an incentive to signal low market demand by choosing a smaller export subsidy compared to a situation with perfect information. The signalling effect may be so large that the domestic country receives a smaller welfare than the foreign country in spite of having both private information and the possibility to use export subsidies.

As mentioned in the introduction, considering the case of bilateral intervention would leave the qualitative signalling effect unaffected. Suppose there is asymmetric information about market demand, and suppose the foreign country sets an export subsidy at time $t = 1$ simultaneously with the domestic country. Then the benchmark case is a situation with perfect information in $t = 2$. That is, we consider a situation in which the domestic country can truthfully reveal its private information to the foreign country and to the foreign firm. Then comparing the Nash equilibrium with asymmetric information with the Nash equilibrium with perfect information, we derive the same results as in Section 3.

Several possible solutions present themselves. At first, the domestic country may be better of by truthfully revealing its private information to the foreign firm. Then at time t=2, there is perfect information about the market demand. Thus, no signalling effect exists, and the domestic country sets the optimal export subsidy. Secondly, if the strategic trade policy has the effect that the domestic country receives less welfare than the foreign country, the domestic country must credibly commit itself to not using the strategic trade policy. Given, that there exists the option of using the strategy trade policy it is individually rational for the domestic country to subsidize its firm. Therefore, it is not credible for the domestic country to commit itself to not using the strategic trade policy. Thirdly, the results demonstrate that the countries may not have an incentive to acquire private information about market demand. If they do not have the private information, they are in a situation with uncertainty, but symmetric information about the market demand. This case is formally equivalent to perfect information, except that true market demand is replaced with the expectations about true market demand.

5 Appendix

Appendix A:

$$
\begin{aligned}
&: && W_1\left(a_h, s_h, a_h\right) = \frac{1}{8}\left(a_h - 2c_1 + c_2\right)^2 \\
&: && W_1\left(a_h, s, a_l\right) = \frac{1}{32}\left(3a_h - a_l - 4c_1 + 2c_2\right)^2 - \frac{2}{9}\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \\
&: && W_1\left(a_h, s_h, a_h\right) \geq W_1\left(a_h, s, a_l\right) \, is \\
&: && \frac{1}{8}\left(a_h - 2c_1 + c_2\right)^2 \geq \frac{1}{32}\left(3a_h - a_l - 4c_1 + 2c_2\right)^2 - \frac{2}{9}\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \\
&\Leftrightarrow && \frac{1}{8}\left(a_h - 2c_1 + c_2\right)^2 - \frac{1}{32}\left(3a_h - a_l - 4c_1 + 2c_2\right)^2 \geq -\frac{2}{9}\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \\
&\Leftrightarrow && \frac{9}{64}\left(3a_h - a_l - 4c_1 + 2c_2\right)^2 - 4\frac{9}{64}\left(a_h - 2c_1 + c_2\right) \leq \left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right)^2 \\
&\Leftrightarrow && \frac{3}{8}\sqrt{\left(3a_h - a_l - 4c_1 + 2c_2\right)^2 - 4\left(a_h - 2c_1 + c_2\right)^2} \leq \pm\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s\right) \\
&\Leftrightarrow && \frac{3}{8}\sqrt{\left(a_h - a_l\right)\left(5a_h + 4c_2 - a_l - 8c_1\right)} \leq \pm\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2\right) \mp s \\
&\Leftrightarrow && \pm s \leq \pm\left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2\right) - \frac{3}{8}\sqrt{\left(a_h - a_l\right)\left(5a_h + 4c_2 - a_l - 8c_1\right)} \\
&\Leftrightarrow && s \leq s_{11} := \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{\left(a_h - a_l\right)\left(5a_h + 4c_2 - a_l - 8c_1\right)}
\end{aligned}
$$

$$
\begin{aligned}
: &\quad s \geq s_{12} := \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 + \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} \\
: &\quad Hence W_1(a_h, s_h, a_h) \geq W_1(a_h, s_l, a_l)\, if and only if s_l \leq s_{11} or s_l \geq s_{12}.
\end{aligned}
$$

Appendix B:

$$
\begin{aligned}
: &\quad Let s_l^p = \frac{1}{4}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2. \\
&\quad s_l^p - s_{11} \\
= &\quad \frac{1}{4}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \left(\frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)}\right) \\
= &\quad \frac{3}{8}a_l - \frac{3}{8}a_h + \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} \\
&\quad s_{12} - s_l^p \\
= &\quad \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 + \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} - \left(\frac{1}{4}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2\right) \\
= &\quad \frac{3}{8}a_h - \frac{3}{8}a_l + \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} \\
: &\quad Since \sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} > a_h - a_l \\
\Leftrightarrow &\quad 5a_h + 4c_2 - a_l - 8c_1 > a_h - a_l \\
\Leftrightarrow &\quad a_h > 2c_1 - c_2 \\
: &\quad it follows that s_l^p - s_{11} > s_{12} - s_l^p > 0.
\end{aligned}
$$

Appendix C:

$$
\begin{aligned}
: &\quad W_1(a_l, s_{lh}, a_h) = \frac{1}{32}(3a_l - a_h - 4c_1 + 2c_2)^2 \\
: &\quad W_1(a_l, s_l, a_l) = \frac{1}{32}(2a_l - 4c_1 + 2c_2)^2 - \frac{2}{9}\left(\frac{1}{4}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - s_l\right)^2 \\
: &\quad With s_l = s_{11} W_1(a_l, s_l, a_l) - W_1(a_l, s_{lh}, a_h)\, is \\
&\quad -\frac{2}{9}s^2 - \frac{2}{9}c_1 s + \frac{1}{9}c_2 s + \frac{1}{9}a_l s - \frac{1}{72}c_2^2 + \frac{1}{18}c_1 c_2 - \frac{1}{18}c_1^2 + \frac{3}{16}a_h a_l - \frac{1}{32}a_h^2 \\
&\quad +\frac{11}{36}a_l c_1 - \frac{11}{72}a_l c_2 + \frac{1}{8}a_h c_2 - \frac{1}{4}a_h c_1 - \frac{49}{288}a_l^2 \\
= &\quad \frac{1}{16}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)}\,(a_h - a_l) - \frac{7}{32}\left(a_h^2 - 2a_h a_l + a_l^2\right) \\
= &\quad \frac{1}{16}\sqrt{a_h - a_l}\sqrt{5a_h + 4c_2 - a_l - 8c_1}\,(a_h - a_l) - \frac{7}{32}(a_h - a_l)^2
\end{aligned}
$$

$$
\begin{aligned}
&= && \frac{1}{32}\left(a_h-a_l\right)^{\frac{3}{2}}\left(2\sqrt{5a_h+4c_2-a_l-8c_1}-\frac{7}{32}\sqrt{a_h-a_l}\right)\geq 0\\
&\Leftrightarrow && 2\sqrt{5a_h+4c_2-a_l-8c_1}-7\sqrt{a_h-a_l}\geq 0\\
&\Leftrightarrow && 2\sqrt{5a_h+4c_2-a_l-8c_1}\geq 7\sqrt{a_h-a_l}\\
&\Leftrightarrow && 4\left(5a_h+4c_2-a_l-8c_1\right)\geq 49a_h-49a_l\\
&\Leftrightarrow && 20a_h+16c_2-4a_l-32c_1\geq 49a_h-45a_l\\
&\Leftrightarrow && 16c_2-32c_1+45a_l\geq 29a_h\\
&\Leftrightarrow && \frac{16}{29}c_2-\frac{32}{29}c_1+\frac{45}{29}a_l\geq a_h\\
&: && With s_l=s_{12}W_1\left(a_l,s_l,a_l\right)-W_1\left(a_l,s_{lh},a_h\right) is\\
& && -\frac{2}{9}s^2-\frac{2}{9}c_1s+\frac{1}{9}c_2s+\frac{1}{9}a_ls-\frac{1}{72}c_2^2+\frac{1}{18}c_1c_2-\frac{1}{18}c_1^2+\frac{3}{16}a_ha_l-\frac{1}{32}a_h^2\\
& && +\frac{11}{36}a_lc_1-\frac{11}{72}a_lc_2+\frac{1}{8}a_hc_2-\frac{1}{4}a_hc_1-\frac{49}{288}a_l^2\\
&= && \frac{1}{16}\sqrt{\left(a_h-a_l\right)\left(5a_h+4c_2-a_l-8c_1\right)}\left(a_l-a_h\right)+\frac{7}{16}a_ha_l-\frac{7}{32}a_h^2-\frac{7}{32}a_l^2\\
&= && \frac{1}{16}\sqrt{\left(a_h-a_l\right)\left(5a_h+4c_2-a_l-8c_1\right)}\left(a_l-a_h\right)-\left(\frac{7}{32}a_h^2-2\frac{7}{32}a_ha_l+\frac{7}{32}a_l^2\right)\\
&= && \frac{1}{16}\sqrt{a_h-a_l}\sqrt{5a_h+4c_2-a_l-8c_1}\left(-1\right)\left(a_h-a_l\right)-\frac{7}{32}\left(a_h-a_l\right)^2\\
&= && \frac{1}{32}\left(a_h-a_l\right)^{\frac{3}{2}}\left(-2\sqrt{5a_h+4c_2-a_l-8c_1}-\frac{7}{32}\sqrt{a_h-a_l}\right)\geq 0\\
& && is a contradiction.
\end{aligned}
$$

Hence $W_1\left(a_l,s_{12},a_l\right)\leq W_1\left(a_l,s_{lh},a_h\right)$. Since $W_1\left(a_l,s_1,a_l\right)$ is a parabolic function opened downwards with maximum at $s_l^p=\frac{1}{4}a_l-\frac{1}{2}c_1+\frac{1}{4}c_2$ and $s_l^p<s_{12}$, it follows that $W_1(a_l,s,a_l)<W_1\left(a_l,s_{12},a_l\right)$ for all $s>s_{12}$ and hence $W_1\left(a_l,s,a_l\right)<W_1\left(a_l,s_{lh},a_h\right)$ for all $s>s_{12}$.

Appendix D:

We only show that the lower restriction is satisfied for s_{11}.

$$
\begin{aligned}
&: && s_{11}>c_1-\frac{1}{2}c_2+\frac{1}{2}\bar{a}-a_l>c_1-\frac{1}{2}c_2+\frac{1}{2}a_l-a_l\\
&\Leftrightarrow && \frac{3}{8}a_h-\frac{1}{8}a_l-\frac{1}{2}c_1+\frac{1}{4}c_2-\frac{3}{8}\sqrt{\left(a_h-a_l\right)\left(5a_h+4c_2-a_l-8c_1\right)}\geq c_1-\frac{1}{2}c_2-\frac{1}{2}a_l\\
&\Leftrightarrow && \frac{3}{8}a_h+\frac{3}{8}a_l-\frac{12}{8}c_1+\frac{6}{8}c_2-\frac{3}{8}\sqrt{\left(a_h-a_l\right)\left(5a_h+4c_2-a_l-8c_1\right)}\geq 0\\
&\Leftrightarrow && 3a_h+3a_l-12c_1+6c_2\geq 3\sqrt{\left(a_h-a_l\right)\left(5a_h+4c_2-a_l-8c_1\right)}
\end{aligned}
$$

$$
\begin{aligned}
\Leftrightarrow \quad & (a_h + a_l - 4c_1 + 2c_2)^2 \geq (a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1) \\
\Leftrightarrow \quad & (a_h + a_l - 4c_1 + 2c_2)^2 - (a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1) \geq 0 \\
\Leftrightarrow \quad & -4a_h^2 + 8a_h a_l - 16a_l c_1 + 8a_l c_2 + 16c_1^2 - 16c_1 c_2 + 4c_2^2 \geq 0 \\
\Leftrightarrow \quad & -4(a_h - 2c_1 + c_2)(a_h - 2a_l + 2c_1 - c_2) \geq 0
\end{aligned}
$$

Appendix E:
The function s_{11} is zero if and only if $a_h = \frac{2}{3}c_1 - \frac{1}{3}c_2 + \frac{2}{3}a_l + \frac{1}{3}\sqrt{2}(c_2 - 2c_1 + a_l)$.

$$
\begin{aligned}
& \lim_{a_h \to \infty} \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{(a_h - a_l)(5a_h + 4c_2 - a_l - 8c_1)} \\
= \quad & \lim_{a_h \to \infty} \frac{3}{8}a_h - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{5a_h^2 + 4a_h c_2 - 6a_h a_l - 8a_h c_1 - 4a_l c_2 + a_l^2 + 8a_l c_1} \\
= \quad & \lim_{a_h \to \infty} a_h \left(\frac{3}{8} - \frac{1}{8}\frac{a_l}{a_h} - \frac{1}{2}\frac{c_1}{a_h} + \frac{1}{4}\frac{c_2}{a_h} - \frac{3}{8}\sqrt{5 + 4\frac{c_2}{a_h} - 6\frac{a_l}{a_h} - 8\frac{c_1}{a_h} - 4\frac{a_l c_2}{a_h^2} + \frac{a_l^2}{a_h^2} + 8\frac{a_l c_l}{a_h^2}} \right) \\
= \quad & \lim_{a_h \to \infty} a_h \left(\frac{3}{8} - \frac{3}{8}\sqrt{5} \right) = -\infty \\
& \lim_{a_h \to a_l} \frac{3}{8}a_l - \frac{1}{8}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 - \frac{3}{8}\sqrt{(a_l - a_l)(5a_l + 4c_2 - a_l - 8c_1)} \\
= \quad & \lim_{a_h \to a_l} \frac{1}{4}a_l - \frac{1}{2}c_1 + \frac{1}{4}c_2 > 0 \\
: \quad & Hencefor a_h > \frac{2}{3}c_1 - \frac{1}{3}c_2 + \frac{2}{3}a_l + \frac{1}{3}\sqrt{2}(c_2 - 2c_1 + a_l) is s_l < 0.
\end{aligned}
$$

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