Choice of Trade Policy for International Oligopoly with Incomplete Information

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1 February 2020

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Abstract

This paper studies the design of trade policies in an uncertain third market with incomplete information. Governments in each of the two countries select either direct quantity controls or export subsidies in an attempt to shift profits in favour of their own firms in an international oligopolistic setting. It is shown that the country with firms having information disadvantage tends to choose the direct quantity control, while the country with well-informed firms would use export subsidy (export quota, respectively) when the degree of uncertainty is sufficiently high (low, respectively).

Journal of Economic Literature classification number: D82, F12, F13, L13.

Keywords: Strategic Trade Policy; Uncertainty; Incomplete Information; Cournot Competition

*I am grateful to Mahmudul Anam, Shin-Hwan Chiang, and Kin Chung Lo for their generous support and countless useful discussions. Financial supports from Dongbei University of Finance and Economics (Grant Numbers: DUFE2020Q11, PT202130) are gratefully acknowledged. All remaining errors are my own responsibility.

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1 Introduction

Strategic trade policy, which has been brought to our attention due to the seminal work by Brander and Spencer (1985), is designed to shift profits towards domestic firms when market in the competing country is oligopolistic (see, for example, Dixit, 1984; Brander and Spencer, 1985; Harris, 1985; Eaton and Grossman, 1986; Mai and Hwang, 1987; Koska and Stähler, 2016; Tsai et al., 2018; Choi and Lim, 2019; Livanis and Geringer, 2021). Through these policies, governments influence the strategic behavior of their own firms in their subsequent market competition with foreign firms. Thus, strategic trade policy provides a new explanation for trade intervention in imperfect competitive international market. Although models of monopolistic competition accommodating firm heterogeneity have been dominating literature in theory of international trade since 2000s, Head and Spencer (2017) empirically show that many international competitions are indeed oligopolistic. They highlight the importance of reincorporating oligopoly models in international trade theory, particularly the policy implications from strategic trade theory.

A key assumption of conventional strategic trade policy models is the complete information about export markets. This overly simplified assumption is not realistic for policymakers since they are unlikely to have full information about market conditions. In response to this concern, economists have been examining the effect of asymmetric information on strategic trade policy (see, for instance, Cooper and Riezman, 1989; Arvan, 1991; Shivakumar, 1993, 1995; Brainard and Martimort, 1996, 1997; Grant and Quiggin, 1997; Maggi, 1999; Anam and Chiang, 2000; Caglayan, 2000; Caglayan and Usman, 2004; Creane and Miyagiwa, 2008; Antoniou and Tsakiris, 2014).

The present paper contributes to this line of literature by considering incomplete information at industrial level. We model a three country trade game à la Cooper and Riezman (1989) with demand uncertainty in the third country, which is the destination market for exports from the other two countries. Similar to Cooper and Riezman (1989), we focus on the choice of trade policy, assuming governments from exporting countries have limited information about demand condition in the third country. Departure from Cooper and Riezman (1989), we assume that one of the exporting firms has an information advantage over the other about market demand condition. Specifically, we let a firm from one of the exporting country has complete information about demand condition in the third country, while a firm from the other country is assumed to be incompletely informed about demand condition in the third market.[1] The assumption of incomplete information at the industrial level can

[1] Collie and Hviid (1994) make a similar assumption of incomplete information about market demand in an importing

be justified as follows. Suppose there are three countries 1, 2 and 3. Firms are located in country 1 and 2, and they export their final homogeneous products solely for country 3 residents. One may think of firm 1 from country 1 being a new entrant with little information about market conditions in country 3, whereas firm 2 from country 2 is an incumbent that has been doing business in country 3 for some time. Therefore, firm 1 cannot perfectly predict tastes of consumers in market 3, while firm 2 is more likely to foresee demand conditions in market 3. For example, Chinese New Energy Vehicles (NEV) manufacture BYD (Build Your Dreams Co. Ltd), being new to the market, is unlikely to know more about the market condition than its American counterpart (e.g., Tesla) as it enters the European NEV passenger vehicle market.[2] It is not difficult to imagine that BYD may not be able to fully anticipate the tastes of European residents, while Tesla has significant advantage in information about market demand in European passenger vehicle markets. Thus, incomplete information at the industrial level is not uncommon in international competition between firms.

Our equilibrium results are significantly different from Cooper and Riezman (1989) in that asymmetric information about market demand in the exporting market between governments and firms is assumed. In Cooper and Riezman (1989), both domestic and foreign firms can fully observe the realized demand after the resolution of market uncertainty. Policymakers can use either price incentives (export subsidies) or direct quantity controls (export quotas) as their strategic policy instruments. Cooper and Riezman (1989) demonstrate that governments will choose export subsidy (export quota, respectively) when the degree of uncertainty in the export market is high (low, respectively). Moreover, they also show that governments tend to choose asymmetric policy instruments if the market volatility in the third country falls in a range of some intermediate values. In the present paper, we show that direct quantity control becomes the dominant strategy for the country with the incompletely informed firm. By contrast, the equilibrium choice between export subsidy and export quota for the country with the fully informed firm depends on the degree of uncertainty in the third market as in Cooper and Riezman (1989).[3] This result is driven by the option value effect associated with firm's ability to make better production decisions. Intuitively, export subsidy, relative to export quota, provides more flexibility for the well-informed firm, thereby creating higher option values under higher degree of uncertainty. This makes export subsidy more attractive for the country with the well-informed firm

country model to evaluate the effect of incomplete information on optimal tariff.

[2]BYD began to export its NEV commercial vehicles (i.e., tour buses) to a few selected countries (e.g., France and Norway) in the European Common Market where Tesla has a lion's share of NEV passenger vehicle market.

[3]Although GATT and WTO restrict use of export subsidies, the export subsidy is the same as the production subsidy in our third market framework. Hence, we keep the term export subsidy as aligning to the literature.

as market uncertainty exceeds some critical cutoff. Clearly, the country would choose export subsidy over export quota when the market volatility is sufficiently high.

Our equilibrium results also significantly differ from two other extensions of Cooper and Riezman (1989). Caglayan (2000) assumes firms from both exporting countries have imperfect information about uncertain demand in the third country, but firms receive a signal about the stochastic term associated with demand function of the third market. Although, in this case, firms have imperfect information about demand in the destination country, the signals firms received equip them with better information than policymakers. Caglayan and Usman (2004) further extend Caglayan (2000) to let both governments receive additional noisy signals about the true state in the third market, and they conclude that both exporting countries are better off if they are less informed about stochastic demand in the third market. Both extensions reach similar policy conclusions as in Cooper and Riezman (1989) that any pairs of policy instruments could form a Nash equilibrium in a choice of trade policy game. Our equilibrium results emphasize that incomplete information at the industrial level eliminates the incentive for the government with the uninformed firm to choose export subsidy – a result that is driven by option value effect.

This paper is organized as follows: section 2 outlines the basic third market model and the structure of multi-stage trade game. Section 3 derives subgame equilibrium for various pairs of policy instruments. Section 4 characterizes and analyzes the optimal choice of policy regimes. Finally, section 5 concludes the paper.

2 The Model

We assume that there are two firms, one domestic (denote as firm 1) and one foreign (denote as firm 2), producing a homogeneous product exclusively for exports.[4] The export competition takes place in a neutral third country where the demand is subject to some random disturbances. For simplicity, assume that the linear inverse demand function in this export market is

$$p = a - b\left(q_1 + q_2\right) + \varepsilon,$$

where q_1 and q_2 represent the export of the domestic firm and the foreign firm, respectively. The parameters a and b are both positive, and ε is a random variable defined over a finite set Ω which

[4]Our model is readily to be extended to have N_1 number of firms in the domestic country and N_2 number of firms in the foreign country as assumed in Cooper and Riezman (1989).

reflects stochastic demand conditions. Without loss of generality, it is assumed that the disturbance term ε is binary, which takes only two possible values: $\varepsilon \in \Omega = \{\varepsilon_l, \varepsilon_h\}$, where $\varepsilon_h > \varepsilon_l$.[5] The subjective common prior probabilities for ε_l and ε_h to occur are θ and $1-\theta$, respectively. Hence the expected value of random variable is $E(\varepsilon) = \theta\varepsilon_l + (1-\theta)\varepsilon_h$, and the variance of random variable is $var\,(\varepsilon) = E\left(\varepsilon^2\right) - E\left(\varepsilon\right)^2 = \sigma^2$.

The cost of production for firm i $(i = 1, 2)$ is assumed to be linear in output, i.e.,

$$C_i = cq_i.$$

Following Cooper and Riezman (1989), our model consists of three stages. In stage one, each government commits to a policy instrument before the realization of random variable ε. The levels of the policy instruments are then set in the second stage, again before the realization of ε. The value of ε becomes known at the beginning of stage three. Unlike Cooper and Riezman (1989), we assume that ε is fully observable to the foreign firm, but such information is not available to the domestic firm. However, the domestic firm does know the distribution of ε. That is, the domestic firm faces information disadvantage in competing with the foreign firm in export competition. This permits us to gain some insights into the effect of incomplete information at the industrial level on policy choices by each country. Both firms play a Cournot-Nash game and set outputs to maximize profits under incomplete information in stage three, given policies chosen by the governments in previous stages. Since the foreign firm sets output after observing realized market demand, it stands to capture the option value associated with being able to wait for the resolution of uncertainty.[6] Figure 1 shows the timing of moves and the (partial) resolution of uncertainty.

Figure 1: Three-stage trade game with incomplete information

Stage 1		Stage 2		Beginning of Stage 3		Stage 3
Governments select policy forms	→	Governments select policy levels	→	Trade policies and levels are revealed to firms, and firm 2 observes ε.	→	Firms select quantities

Before getting into the heart of the present model, it may be useful to consider the case where there is no government intervention and firms can fully observe the market condition when ε is realized.

[5] Unlike Cooper and Riezman (1989)'s disturbance term that follows continuous distribution with mean zero, the assumption of binary random variable in this paper is made for ease of exposition.

[6] See Dixit and Pindyck (1994) for a definition of option value in the context of investment under uncertainty.

Under this limiting case, firm i's profit is therefore

$$\pi_i = (p - c)q_i,$$

for $i = 1, 2$. One can easily verify that the Cournot-Nash equilibrium of output is

$$q_i^* = \frac{a - c + \varepsilon}{3b},$$

for $i = 1, 2$. For the output to be non-negative, it requires $a - c + \varepsilon \geq 0$. This benchmark case serves as a basis for comparison when the governments seek to shift profits in favor of their native firms by providing an export subsidy (see Brander and Spencer, 1985).

In what follows, we construct a three-stage perfect Bayesian equilibria for various policy regimes using backward induction. Subsidy and quota games are examined in sequence and their welfare implications are compared. By using this approach, we can guarantee that the equilibrium is a perfect Bayesian equilibrium.

3 Equilibrium of Subgames

In this section, we derive equilibrium levels of output produced by firms and levels of governments' intervention using Bayesian Nash solution concept in each subgame (stage two and stage three under various policy combinations). For each subgame, expected social welfare for both countries are also derived.

3.1 Bilateral Subsidy Game

We first consider the subgame, where export subsidies are committed to firms by governments as the instruments of protection in stage one. The solution through backward induction starts in stage three when ε becomes known to firm 2.

Stage three game involves two firms, and it has two states of nature (ε_l and ε_h) that are asymmetrically revealed to the firms involved. The possible actions of each firm are the amount of outputs (or exports) which is defined in $\mathbb{R}_+$. Technically, this is a strategic game of incomplete information (a Bayesian game). In what follows, we characterize the Bayesian Nash equilibrium for stage three game. Specifically, each firm maximizes its (expected) profit by setting quantities given conjectures on the quantities chosen by its rival. In a Bayesian Nash equilibrium, these conjectures will be confirmed.

Let s_i be the specific export subsidy prescribed by governments i to its own firm. Being unable to observe the true state of nature, firm 1 thus chooses q_1 to maximize its expected profit. This is given by

$$E(\pi_1) = \theta \left(\left(a - b \left(q_1 + q_2^l \right) + \varepsilon_l \right) q_1 \right) + (1-\theta) \left(\left(a - b \left(q_1 + q_2^h \right) + \varepsilon_h \right) q_1 \right) - cq_1 + s_1 q_1, \tag{1}$$

where θ and $1-\theta$ are the subjective probabilities associated with ε_l and ε_h.

On the other hand, firm 2 is able to observe the true state of nature when it enters stage three game. Hence, firm 2 can make its production decision according to the demand condition. If $\varepsilon = \varepsilon_l$, firm 2 chooses q_2^l to maximize its profit:

$$\pi_2^l = \left(a - b \left(q_1 + q_2^l \right) + \varepsilon_l \right) q_2^l - cq_2^l + s_2 q_2^l. \tag{2}$$

Conversely, if $\varepsilon = \varepsilon_h$, firm 2 sets q_2^h so as to maximize

$$\pi_2^h = \left(a - b \left(q_1 + q_2^h \right) + \varepsilon_h \right) q_2^h - cq_2^h + s_2 q_2^h. \tag{3}$$

The best response functions for the above maximization problems are given by

$$\begin{aligned} BR_1(q_2^l, q_2^h) &= q_1 \in \arg\max E(\pi_1), \\ BR_{2l}(q_1) &= q_2^l \in \arg\max \pi_2^l, \\ BR_{2h}(q_1) &= q_2^h \in \arg\max \pi_2^h. \end{aligned}$$

Given these, we obtain the Bayesian Nash equilibrium points as follows:

$$\begin{aligned} q_1 &= \frac{a-c+2s_1-s_2}{3b} + \frac{E(\varepsilon)}{3b}, \\ q_2^l &= \frac{a-c-s_1+2s_2}{3b} + \frac{\varepsilon_l}{2b} - \frac{E(\varepsilon)}{6b}, \\ q_2^h &= \frac{a-c-s_1+2s_2}{3b} + \frac{\varepsilon_h}{2b} - \frac{E(\varepsilon)}{6b}. \end{aligned} \tag{4}$$

These equations characterize the Bayesian Nash equilibrium points in market 3 for given values of $(s_1, s_2, \varepsilon_l, \varepsilon_h, \theta)$. Notice that higher values of s_1 leads increasing output by country 1's firm, while higher values of s_2 from its rival country causes firm 1's output to fall. This is due to the fact that governments recognize increasing export subsidy levels lead to output expansions by their firms and output reductions by rival firms. This is the same as the conventional view on profit shifting motivation in Brander and Spencer (1985).

In stage two, both governments maximize their expected social welfare by choosing export subsidy levels, and they take into account the responses from firms in stage three. That is, a government's objective is to choose a value for the ex post subsidy that maximizes the expected value of its firm's profit net of subsidies since we can ignore consumer's surplus due to absence of domestic consumers. This implies that income distribution is not an important determinant of social welfare for each country.

Information partition for both countries indicates both countries have no information about true demand in country 3, and country 1 only anticipates its firm has one reaction function of output level in the following stage (due to lack of information). We can write expected social welfare for country 1 as

$$E(SW_1) = E(\pi_1) - s_1 q_1, \tag{5}$$

where

$$E(\pi_1) = \frac{\left(a - c + 2s_1 - s_2 + E(\varepsilon)\right)^2}{9b}.$$

On the other hand, country 2 knows its firm will have complete information about true demand in market 3, then country 2's expected social welfare given the common prior $(\theta, 1-\theta)$ over Ω can be written as

$$E(SW_2) = \theta\left(\pi_2^l - s_2 q_2^l\right) + (1-\theta)\left(\pi_2^h - s_2 q_2^h\right), \tag{6}$$

where

$$\begin{aligned} \pi_2^l &= \frac{(2a - 2c - 2s_1 + 4s_2 + 3\varepsilon_l - E(\varepsilon))^2}{36b}, \\ \pi_2^h &= \frac{(2a - 2c - 2s_1 + 4s_2 + 3\varepsilon_h - E(\varepsilon))^2}{36b}. \end{aligned}$$

Similar to solving Bayesian Nash equilibrium points in the third stage, each country maximizes its expected social welfare by setting export subsidy levels given conjectures on the levels chosen by the other government in the second stage.

Government i's best response function in stage two game is given by

$$BR_i(s_j) = s_i \in \arg\max E(SW_i), \forall i = 1, 2, i \neq j.$$

Solving each government's best response function simultaneously yields the Bayesian Nash equilibrium level of specific export subsidy as

$$s_i^* = \frac{a-c}{5} + \frac{E(\varepsilon)}{5}. \tag{7}$$

Note that $s_i > 0$ for $i = 1, 2$. That is, both governments choose to subsidize their own firm. It is worth noting that the equilibrium export subsidy levels are symmetric for both governments even with incomplete information at the industrial level. This is because governments 1 and 2 hold the same prior beliefs about random variable ε and $q_1 = \theta q_2^l + (1-\theta) q_2^h$. Also note that when $E(\varepsilon) = 0$, the equilibrium export subsidy is reduced to the export subsidy obtained by Cooper and Riezman (1989) even though information symmetry at the industrial level is assumed in their paper.

Substituting equation (7) into the expected social welfare functions for both governments, we get

$$E(SW_1) = \frac{2((a-c)+E(\varepsilon))^2}{25b}, \tag{8}$$

$$E(SW_2) = \frac{2((a-c)+E(\varepsilon))^2}{25b} + \frac{\sigma^2}{4b}. \tag{9}$$

Notice that $E(SW_2)$ is the sum of firm's profits net of export subsidy, and it has an additional variance term capturing the option value effect (see Dixit and Pindyck, 1994) which is absent in $E(SW_1)$. This indicates that higher variance of ε benefits the country with the better informed firm (i.e., country 2 in our model). This can be seen by calculating

$$\frac{\partial E(SW_2)}{\partial \sigma^2} = \frac{1}{4b} > 0,$$

and

$$E(SW_2) - E(SW_1) = \frac{1}{4b}(\sigma^2) > 0.$$

Obviously, if there is no uncertainty in demand (hence no information problem), we obtain the classical result of Brander and Spencer (1985). This gives us

Proposition 1. *Under a bilateral subsidy game, the difference in expected social welfare between two countries is the option value effect enjoyed by the country with the well-informed firm. Moreover, the expected social welfare for country with the well-informed firm increases with market volatility.*

Surprisingly, more information at the industrial level does not always benefit the foreign firm. This occurs when $\varepsilon = \varepsilon_l$. Specifically, firm 2's (ex ante) expected profit is lower (higher, respectively) than firm 1's expected profit if the true market demand in country 3 is low (high, respectively). To see this, calculate

$$\begin{aligned} E(\pi_1) &= \frac{4(a-c+E(\varepsilon))^2}{25b}, \\ E(\pi_2^l) &= \frac{(4a-4c+5\varepsilon_l-E(\varepsilon))^2}{100b}, \\ E(\pi_2^h) &= \frac{(4a-4c+5\varepsilon_h-E(\varepsilon))^2}{100b}. \end{aligned} \tag{10}$$

It can be easily verified that $E\left(\pi_2^l\right) < E\left(\pi_1\right) < E\left(\pi_2^h\right)$. This is because firm 1 with incomplete information about market demand always produces the moderate level of output (i.e., a weighted average output level given $(\theta, 1-\theta)$ over Ω). Nevertheless, when the true demand is low, firm 2 will be forced to produce less than expected, given that firm 1 is incapable of reacting to it for lack of information. Conversely, when the true demand is high, firm 2 will respond by producing much more to take advantage of good market conditions, given that it anticipates no action from firm 1.

It is also worth noting the differences among $E(\pi_2^l)$, $E(\pi_1)$ and $E(\pi_2^h)$ depend on the common prior $(\theta, 1-\theta)$ over Ω. For any fixed parameters, if firm 1 is more pessimistic (i.e., a higher θ), it will lose more profit relative to firm 2 in high demand. But if firm 1 is more optimistic (i.e., a lower θ), the opposite is true.

3.2 Bilateral Quota Game

Here, we look into the equilibrium under bilateral export quotas. In this case, governments impose export level restrictions for their own firm in the second stage. Similar to Cooper and Riezman (1989), we assume that export quota levels set by both governments are the maximum levels of quantities firms can export to market 3 (i.e., a Voluntary Export Restraint). Without loss of generality, we assume that export quotas are binding for both firms in both countries as in Cooper and Riezman (1989).[7] That is, both firms will produce positive outputs in stage three, given export restrictions set by their home governments in stage two under bilateral quota policy.

Each government sets an export ceiling to the third market for their respective firms in stage two. Since the actions taken by both governments occur before the resolution of random variable, each government chooses $\overline{q}_i$ (for $i = 1, 2$) so as to maximize their firm's expected profits (same as their

[7] Caglayan (2000) and Caglayan and Usman (2004) also assume export quotas are always binding. In our model, export quota will always be binding for firm 1 since the true state of nature is not observable. But for firm 2, it is possible that quota may not be binding particularly when the realized ε_l is sufficiently low. When this occurs, our results remain intact.

expected social welfare due to absence of domestic consumers) given by

$$E(\pi_i) = \theta\left(\left(a - b\overline{Q} + \varepsilon_l\right)\overline{q}_i\right) + (1-\theta)\left(\left(a - b\overline{Q} + \varepsilon_h\right)\overline{q}_i\right) - c\overline{q}_i, \tag{11}$$

where $\overline{Q} = \overline{q}_1 + \overline{q}_2$, and it is denoted as aggregate output in market 3 under bilateral quota policy.

Government i's best response function is

$$BR_i(\overline{q}_j) = \overline{q}_i \in \arg\max E(\pi_i), \forall i = 1, 2, i \neq j.$$

Solving each government's best response function simultaneously yields the Bayesian Nash equilibrium level of export quota for government i:

$$\overline{q}_i^* = \frac{a - c + E(\varepsilon)}{3b}, \forall i = 1, 2. \tag{12}$$

Substituting equation (12) into firm's expected profit functions, we obtain the expected social welfare for country i as follows:

$$E(SW_i) = \frac{\left((a-c) + E(\varepsilon)\right)^2}{9b}, \forall i = 1, 2. \tag{13}$$

It is worth noting that both governments end up with same level of social welfare under bilateral export quota game. In this case, there is no option value to be had for firm 2 even though it has more information about the market condition than firm 1 does. With output being state independent under export quota, the well-informed firm loses the option of setting output according to the market conditions and therefore, there is no option value effect associated with information advantage for country 2.

Next, we turn to examine equilibrium for mixed policy games.

3.3 Quota/Subsidy Mixture Game

So far we have derived subgame equilibrium when both governments choose symmetric strategies. We now consider two subgames that governments 1 and 2 choose to intervene with asymmetric policy instruments.

We first consider the subgame that government 1 chooses direct quantity control while government

2 decides to subsidize its own firm. Since a quota is always binding for firm 1, this limits what firm 1 can sell to the third market. Letting $\overline{q}_1$ be the export quota level imposed on firm 1 by government 1, firm 2's profits for $\varepsilon = \varepsilon_h$ and $\varepsilon = \varepsilon_l$ in stage three game are

$$\pi_2^l = \left(a - b\left(\overline{q}_1 + q_2^l\right) + \varepsilon_l\right) q_2^l - cq_2^l + s_2 q_2^l, \tag{14}$$

$$\pi_2^h = \left(a - b\left(\overline{q}_1 + q_2^h\right) + \varepsilon_h\right) q_2^h - cq_2^h + s_2 q_2^h. \tag{15}$$

Therefore, in stage three game, firm 2 chooses q_2^l and q_2^h to maximize π_2^l and π_2^h given it observes $\overline{q}_1$, respectively. The best response functions for firm 2's problems are

$$BR_{2l}(\overline{q}_1) = q_2^l \in \arg\max \pi_2^l,$$

$$BR_{2h}(\overline{q}_1) = q_2^h \in \arg\max \pi_2^h.$$

Solving yields

$$q_2^l = \frac{a - c + s_2 - b\overline{q}_1 + \varepsilon_l}{2b}, \tag{16}$$

$$q_2^h = \frac{a - c + s_2 - b\overline{q}_1 + \varepsilon_h}{2b}, \tag{17}$$

given any level of s_2 and export quota level set by government 1 on firm 1.

Given these, government 1 then chooses the export quota level while government 2 selects optimal subsidy level in stage two. For our third market model, the expected social welfare for country 1 can therefore be written as

$$E\left(SW_1\right) = \theta\left(\left(a - b\left(\overline{q}_1 + q_2^l\right) + \varepsilon_l\right)\overline{q}_1\right) + (1-\theta)\left(\left(a - b\left(\overline{q}_1 + q_2^h\right) + \varepsilon_h\right)\overline{q}_1\right) - c\overline{q}_1. \tag{18}$$

On the contrary, the expected social welfare for country 2 is specified as producer's surplus net of subsidy, given by

$$E\left(SW_2\right) = \theta\left(\pi_2^l - s_2 q_2^l\right) + (1-\theta)\left(\pi_2^h - s_2 q_2^l\right), \tag{19}$$

where

$$
\begin{aligned}
\pi_2^l &= \frac{\left(a - c + s_2 - b\overline{q}_1 + \varepsilon_l\right)^2}{4b}, \\
\pi_2^h &= \frac{\left(a - c + s_2 - b\overline{q}_1 + \varepsilon_h\right)^2}{4b}.
\end{aligned}
$$

Government 1 chooses $\overline{q}_1$ to maximize its expected social welfare, while government 2 chooses s_2 to maximize its expected social welfare simultaneously. The best response functions for stage two game are given by

$$
\begin{aligned}
BR_1(s_2) &= \overline{q}_1 \in \arg\max E\left(SW_1\right), \\
BR_2(\overline{q}_1) &= s_2 \in \arg\max E\left(SW_2\right).
\end{aligned}
$$

Solving these best response functions simultaneously yields Bayesian Nash equilibrium policy levels:

$$
\overline{q}_1^* = \frac{a - c + E\left(\varepsilon\right)}{2b}, \tag{20}
$$

$$
s_2^* = 0. \tag{21}
$$

It is worth noting that the optimal policy for government 2 is not to intervene at all. The reason behind this result is that firm 2 knows what firm 1 will produce given the export quota is binding for firm 1. Moreover, firm 2 can also fully observe the true market demand, hence it can act accordingly. Profit maximization by firm 2 ensures social welfare maximization for the entire country. Therefore, there is no role for government 2 to play.[8] This explains $s_2^* = 0$.

Substituting $s_2^* = 0$ into firm 2's best response functions, we get the (ex ante) expected output for firm 2 in equilibrium:

$$
\begin{aligned}
E(q_2^l) &= \frac{a - c}{4b} + \frac{\varepsilon_l}{2b} - \frac{E\left(\varepsilon\right)}{4b}, \\
E(q_2^h) &= \frac{a - c}{4b} + \frac{\varepsilon_h}{2b} - \frac{E\left(\varepsilon\right)}{4b}.
\end{aligned}
$$

[8] Note that the first order derivative of (19) yields $s_2 = 0$.

The corresponding expected social welfare for each country in this subgame are

$$E\left(SW_1\right) = \frac{\left((a-c)+E\left(\varepsilon\right)\right)^2}{8b}, \tag{22}$$

$$E\left(SW_2\right) = \frac{\left((a-c)+E\left(\varepsilon\right)\right)^2}{16b} + \frac{\sigma^2}{4b}. \tag{23}$$

Note that the second term in country 2's social welfare is the option value associated with better information. It is easy to verify that the expected social welfare for country 2 increases as market volatility increases. Moreover, it is straightforward to obtain

$$E\left(SW_2\right) - E\left(SW_1\right) > (<)\ 0,$$

if and only if

$$\sigma^2 > (<) \frac{\left((a-c)+E\left(\varepsilon\right)\right)^2}{4}.$$

This implies that country 2 is better off (worse off, respectively) relative to country 1 when the degree of uncertainty is sufficiently high (low, respectively).

3.4 Subsidy/Quota Mixture Game

We now turn to the last subgame that government 1 chooses specific subsidy while government 2 imposes direct quantity control. Since there is incomplete information at the industrial level, expected social welfare for each government in this subgame cannot be symmetrically determined from the previous subsection. As usual, our analysis starts from the last stage. Firm 1 does not know the true market demand in the third market, but it can however observe the export quota level $\overline{q}_2$ set by government 2. Firm 1's expected profit function in stage three game is

$$E\left(\pi_1\right) = \theta\left(\left(a - b\left(q_1 + \overline{q}_2\right) + \varepsilon_l\right) q_1\right) + (1-\theta)\left(\left(a - b\left(q_1 + \overline{q}_2\right) + \varepsilon_h\right) q_1\right) - cq_1 + s_1 q_1. \tag{24}$$

Being unable to observe the realized demand, firm 1 produces a fixed state-independent output for the third market given $\overline{q}_2$. Thus, it chooses q_1 to maximize its expected profit, and its best response function at stage three is given by

$$BR_1(\overline{q}_2) = q_1 \in \arg\max E\left(\pi_1\right).$$

Solving this yields

$$q_1 = \frac{a - c + s_1 + E(\varepsilon) - b\overline{q}_2}{2b},$$

given any level of s_1 and the export quota level set by government 2 to firm 2.

In stage two, government 1 sets the specific export subsidy s_1 to maximize its expected social welfare (specified as producer's surplus net of subsidy) given by

$$E(SW_1) = E(\pi_1) - s_1 q_1, \tag{25}$$

where

$$E(\pi_1) = \frac{(a - c + s_1 + E(\varepsilon) - b\overline{q}_2)^2}{4b}.$$

At the same time, government 2 selects the export quota level $\overline{q}_2$ to maximize its social welfare (specified as producer's surplus):

$$E(SW_2) = \theta\left((a - b(q_1 + \overline{q}_2) + \varepsilon_l)\overline{q}_2\right) + (1-\theta)\left((a - b(q_1 + \overline{q}_2) + \varepsilon_h)\overline{q}_2\right) - c\overline{q}_2 \tag{26}$$

The best response functions for each government at stage two game can be symmetrically specified from the previous subsection, solving yields Bayesian Nash equilibrium policy level:

$$\begin{aligned} s_1^* &= 0, & (27) \\ \overline{q}_2^* &= \frac{a - c + E(\varepsilon)}{2b}. & (28) \end{aligned}$$

Surprisingly, the optimal policy regime is symmetric as in subsection 3.3 . Here, government 1 now grants no subsidy to firm 1 if government 2 imposes an export quota on firm 2. This can be explained as follows. Government 1 makes its choice based on its conjecture on government 2's best response. If there is no deviation from government 2's actual choice, then the Bayesian Nash equilibrium holds in stage two. Since government 1 and firm 1 have same information partition over Ω and firm 1 is well informed about the export quota level imposed by government 2 at the beginning of stage three, firm 1 actually knows what firm 2 will produce. In this case, firm 2 loses the option of responding to market conditions since its output is fixed by the export quota and is therefore no longer state contingent. As a result, government 1 would leave full decision to its own firm (i.e., firm 1) since profit maximization ensures social welfare maximization in the third market setting.[9] In short, government 1 would choose zero subsidy.

Substituting stage two equilibrium points into firm 1's best response function, we get the expected output of firm 1 in stage three:

$$E(q_1) = \frac{a-c}{4b} + \frac{E(\varepsilon)}{4b}.$$

The corresponding expected social welfare for both countries are

$$E(SW_1) = \frac{((a-c)+E(\varepsilon))^2}{16b}, \tag{29}$$

$$E(SW_2) = \frac{((a-c)+E(\varepsilon))^2}{8b}. \tag{30}$$

This together with the finding in subsection 3.2 imply that the export quota essentially eliminates firm's ability to react to market conditions after the resolution of uncertainty. Hence no option value available for the country with the better-informed firm. This can be seen from expected social welfare for government 2 that has no σ^2 term (captures the option value effect) under bilateral quota game and subsidy/quota mixture game. This gives us

Proposition 2. *The export quota eliminates option values for the country with the well-informed firm.*

We are now ready to endogenize the choice of policy regimes. To this end, a normal form representation of stage one game is constructed next.

4 Choice of Trade Policy

We now formally define a (reduced form) strategic game of choice of trade policy at the first stage using expected social welfare derived in each subgame. Let a 5-tuple $G \equiv < N, (A_i), (SW_i), f, (\succeq_i) >$ be a strategic game of choice of trade policy. The specification of the game G is as follows:

i. the finite set of players N consist of two players: government 1 and 2;

ii. for each government $i \in N$, the set of actions $A_i \equiv \{Subsidy, Quota\}$;

iii. the set SW_i represents the set of expected social welfare for government i;

iv. a function $f : A_i \to SW_i$ associates consequences with action profiles;

[9] The first order derivatives associated with (25) yields $s_1 = 0$.

v. for each government $i \in N$, the preference relation of government i is $\succeq_i$ over SW_i.[10]

We introduce a set of expected social welfare SW here because each government cares about its social welfare, but not about the profiles of export subsidy or export quota level generate that social welfare level.

Normal form representation of game G is illustrated in Table 1. Government 1 is the row player and government 2 is the column player. The first expression in each cell is the expected social welfare level for country 1, and the second expression in each cell is the expected social welfare level for country 2.

Table 1: Normal form representation of game G

Government 1	Government 2: Subsidy	Government 2: Quota
Subsidy	$\frac{2((a-c)+E(\varepsilon))^2}{25b}, \frac{2((a-c)+E(\varepsilon))^2}{25b} + \frac{\sigma^2}{4b}$	$\frac{((a-c)+E(\varepsilon))^2}{16b}, \frac{((a-c)+E(\varepsilon))^2}{8b}$
Quota	$\frac{((a-c)+E(\varepsilon))^2}{8b}, \frac{((a-c)+E(\varepsilon))^2}{16b} + \frac{\sigma^2}{4b}$	$\frac{((a-c)+E(\varepsilon))^2}{9b}, \frac{((a-c)+E(\varepsilon))^2}{9b}$

In order to illustrate Nash equilibrium of game G, we adopt the rationalizability concept by Pearce (1984) for presentation purpose. It follows that the game G is dominant solvable. We begin by proving the following lemma.

Lemma 1. *Subsidy is a strictly dominated strategy for government 1.*

Proof. See Appendix A □

Therefore, *Subsidy* will never be chosen by government 1. In other words, government 1 will always prefer to choose *Quota* irrespective of the policy choice of government 2. In view of *Subsidy* being a strictly dominated strategy for government 1, government 2 will respond by choosing a quota (subsidy) if $\sigma^2 \leq (>) \frac{7}{36} ((a-c) + E(\varepsilon))^2$. This is proven in the following lemma.

Lemma 2. *The optimal strategy for government 2 depends on the variance over Ω. Specifically, a quota (subsidy) is chosen if $\sigma^2 \leq (\geq) \frac{7}{36} ((a-c) + E(\varepsilon))^2$.*

Proof. See Appendix B □

[10]For example, an action $a_i \succeq a'_i$ if and only if $f(a_i, a_{-i}) \succeq f(a'_i, a_{-i})$ $\forall a_i, a'_i \in A_i$.

As we can see, for a small variance, setting *Quota* becomes the dominant strategy for government 2. Since neither governments has information advantage over each other, there is no option value to country 2, and both countries end up having the same expected level of social welfare. On the other hand, for sufficiently large variance, choosing *Subsidy* becomes the dominant strategy for government 2. The option value (σ^2 term) accounts for a significant part of social welfare for country 2. By lemmas 1 and 2, we have the following proposition.

Proposition 3. *In a multi-stage third market trade game with incomplete information at the industrial level, the government with the less-informed firm chooses export quota regardless of market uncertainty, while the government with the well-informed firm chooses export subsidy (export quota, respectively) when the market volatility is high (low, respectively). This result is driven by the option value effect. Specifically, the Nash equilibrium of game G is*

i. $(Quota, Quota)$ *if* $\sigma^2 \leq \frac{7}{36}\left((a-c)+E(\varepsilon)\right)^2$;

ii. $(Quota, Subsidy)$ *if* $\sigma^2 \geq \frac{7}{36}\left((a-c)+E(\varepsilon)\right)^2$.

In Cooper and Riezman (1989), both firms have complete information about market demand condition in the third market, and any four pairs of governments' strategies can become Nash equilibrium trade policy choice depending on the market volatility. More specifically, export subsidy (export quota, respectively) is preferred by both governments for high (low, respectively) degree of uncertainty, and asymmetric policies are chosen by governments for some intermediate values of market volatility.

In the present model, incomplete information at the industrial level alters the strategic choices for firms and governments. Although the strategic behavior of the well-informed firm is qualitatively similar to firms in Cooper and Riezman (1989) (with different cutoff point for variance term), the less-informed firm now can only export a state independent amount to the third market due to lack of information about the true market demand. This eliminates the possibility for the less-informed firm's country to enjoy option value, no matter which policy instrument is chosen by the government with the less-informed firm in the first place. Thus, the flexibility provided by setting export subsidy is no longer attractive to the government with the less-informed firm. In fact, the flexibility provided by setting export subsidy can only be beneficial to the country with the well-informed firm. As a consequence, the government with the less-informed firm would strictly prefer export quota over export subsidy regardless of market volatility in the third country. This makes *Quota* a superior strategic choice for the country with the less-informed firm. On the other hand, the government with the well-informed firm would prefer export quota over export subsidy if the market volatility is low in the third market, and it is willing to trade the strategic advantage of export quota for the flexibility provided by export subsidy if the degree of uncertainty is high enough in the third market. That is, incomplete information at the industrial level redistributes the option value from the country with the less-informed firm to the country with the well-informed firm. But the option value is accrued to the country with the well-informed firm only if the variance is sufficiently large. In short, the possibility of getting $(Subsidy, Subsidy)$ and $(Subsidy, Quota)$ as Nash equilibrium outcomes in our model is eliminated by incomplete information at the industrial level.

The policy implication of our equilibrium result is straightforward. For a domestic firm producing a product solely for exporting purpose and having little information about market conditions in the destination country, our theory shows that the domestic government is better off in setting an export quota (i.e., a VER) for its firm no matter how volatile the destination market demand is. This policy holds regardless of policy choice by the foreign government with an incumbent firm. Nevertheless, the foreign government's optimal trade policy crucially depends on its perceived degree of uncertainty of market demand in the destination country. Evidently, Chinese NEV manufacture BYD is expanding its oversea sales to EU where the US NEV manufacture Tesla has already occupied a lion's share of EU NEV passenger vehicle market. Being a new entrant to EU passenger vehicle market, BYD may not be able to fully capture preferences of customers in EU, while Tesla could fully anticipate consumers' preference based on its past experience. It is suggested by our theory that China would be better off by imposing a VER on BYD's exports regardless of market volatility in EU or policy instrument chosen by US. Hence, our equilibrium analysis provides a justification for the use of VER especially when the domestic firm faces information disadvantage in the exporting market.[11]

5 Conclusion

The literature on the choice of strategic trade policy in oligopolistic industry under uncertainty points to a variety of combinations of modes of intervention that could emerge as an equilibrium outcome in a three-country setting (see Cooper and Riezman, 1989). When we consider policymakers choosing between export subsidy and export quota, the optimal choice of trade policy depends on the degree of uncertainty in the third market, and all four combinations of subsidy and quota could be equilibrium under demand uncertainty. The novelty of this paper is that it analyzes the optimal choice of strategic

[11] See Harris (1985) for a conventional view of using VER in an oligopolistic setting under complete information.

trade policy in a third market model when information is incomplete across the duopoly exporters to the third market.

Our principle results can be summarized as follows. In a choice of trade policy game, export subsidy is a dominated strategy for country with incompletely informed firms. In other words, imposing direct quantity control is always optimal for country with incompletely informed firm irrespective of what form of interventions is chosen by the other country. This holds for any degree of market demand uncertainty. For country with completely informed firm, the optimal choice of trade policy depends on the volatility of market demand in the third country. If the market demand in the third country is relatively stable, imposing export quota is optimal. Conversely, if the market demand in the third country is relatively volatile, subsidy turns out to be the optimal choice. This is driven by the option value effect associated with better information.

Our analysis rests heavily on a number of simplifying assumptions. Firstly, the specification of the demand structure is linear with an additive shock. A more general setting with respect to the demand function could be introduced. Secondly, the source of uncertainty is unique in our theoretical framework. We only consider the single source of uncertainty in market demand. In addition to country specific shocks, one may introduce a richer environment of uncertainty by taking firm specific shocks into consideration. Thirdly, we have assumed that consumers only reside in the third country. This assumption is only appropriate if the good is produced solely for export or if the domestic market can be isolated from trade policies by the use of consumption subsidies/taxes. This assumption simplifies our analysis since consumer's surplus is excluded from social welfare calculation. A more realistic setting may include the domestic consumption of goods produced by the domestic firms. Finally, we only consider Cournot competition in the present paper, additional insights from incomplete information at the industrial level might be gained by considering Bertrand competition with differentiated products, but we leave it for future research.

Appendices

A Proof of Lemma 1

Proof. Let $B_1(a_2)$ be the set of government 1's best responses

$$B_1(a_2) \equiv \{a_1 \in A_1 | (a_1, a_2) \succeq_1 (a_1', a_2) \forall a_1' \in A_1\}.$$

Given government 2 chooses *Subsidy*, we have

$$B_1(Subsidy) = \{Quota\},$$

since $f(Quota, Subsidy) \succ_1 f(Subsidy, Subsidy)$ or $\frac{((a-c)+E(\varepsilon))^2}{8b} > \frac{2((a-c)+E(\varepsilon))^2}{25b}$.

Similarly, given government 2 chooses *Quota*, we have

$$B_1(Quota) = \{Quota\},$$

since $f(Quota, Quota) \succ_1 f(Subsidy, Quota)$ or $\frac{((a-c)+E(\varepsilon))^2}{9b} > \frac{((a-c)+E(\varepsilon))^2}{16b}$.

Hence we have

$$B_1(a_2) = \{Quota\} \quad \forall a_2 \in A_2.$$

□

B Proof of Lemma 2

Proof. Let $B_2(Quota)$ be the set of government 2's best responses to government 1's strategy *Quota*

$$B_2(Quota) \equiv \{a_2 \in A_2 | (Quota, a_2) \succeq_2 (Quota, a_2')\}.$$

If $f(Quota, Quota) \succeq_2 f(Quota, Subsidy)$, we have $\frac{((a-c)+E(\varepsilon))^2}{9b} \geq \frac{((a-c)+E(\varepsilon))^2}{16b} + \frac{\sigma^2}{4b}$, that is

$$B_2(Quota) = \{Quota\} \qquad if \quad \sigma^2 \leq \frac{7}{36}((a-c)+E(\varepsilon))^2.$$

On the other hand, if $f(Quota, Subsidy) \succeq_2 f(Quota, Quota)$, we have $\frac{((a-c)+E(\varepsilon))^2}{16b} + \frac{\sigma^2}{4b} \geq$

$\frac{((a-c)+E(\varepsilon))^2}{9b}$, that is

$$B_2\left(Quota\right) = \left\{Subsidy\right\} \qquad if \quad \sigma^2 \geq \frac{7}{36}\left(\left(a-c\right)+E\left(\varepsilon\right)\right)^2.$$

Thus the best response to government 1's strategy *Quota* for government 2 depends on σ^2. $\square$

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