Reveiw of International Economics 3(1), 1995, 75-85

Strategic Trade Policy under Uncertainty

by

Larry D. Qiu

Department of Economics
Hong Kong University of Science and Technology
Kowloon, Hong Kong
Tel number: +(852)2358-7628
Fax number: +(852)2358-2084
Email: larryqiu@ust.hk
Web site: http://www.bm.ust.hk/~larryqiu

Abstract

This paper extends the Brander-Spencer (1985) model by considering market uncertainty, exploring nonlinear policy, and examining firms' choices of strategic variables. By investigating the interrelationship between trade policy and market conduct, we find that unlike the often-studied linear policy, a nonlinear policy can influence the domestic firm's choice of strategic variables and hence alter the market conduct in favor of the domestic country. Therefore, a nonlinear policy proves *strictly* superior to a linear one.

1. Introduction

The literature of strategic trade policy has been flourishing since the early 1980s. The general idea underlying studies in this literature is the following: Because firms earn positive rents in imperfect competition, a government may adopt an appropriate trade policy to affect the strategic interaction between domestic firms and foreign rival firms such that the domestic firms' profits can be increased at the expense of the foreign firms (in quantity competition) or consumers (in price competition). Following this line, various optimal trade policies are derived under different assumptions about market conduct (i.e., type of market competition, e.g., Cournot and Bertrand), product nature, and number of competitors.[1] However, all existing studies except Laussel (1992) share one shortcoming: Policies are linear and the optimal ones are derived for *given* market conduct. In the spirit of the Lucas critique, we shall expect that a firm's choice of strategic variables, price or quantity, could be affected by the trade policy per se, and therefore the type of market conduct cannot be taken as unchanged.[2] The purposes of the present study are to examine nonlinear export policies when market conduct is endogenously determined and to compare them with linear ones.

It is well known that the optimal strategic export policy varies depending on the type of market conduct. In their seminal paper, Brander and Spencer (1985, BS hereafter) argue that policies precommitted by a government could have strategic effects on export market competition. In particular, they find that if firms compete in quantities, an export subsidy can shift part of a foreign firm's market share to a domestic firm and therefore raise the national welfare. Eaton and Grossman (1986), on the other hand, show that if firms compete in prices, the optimal policy is an export tax, which increases both the domestic and foreign firms' profits at the expense of consumers. In both cases, the optimal policies put the domestic firm in the Stackelberg leader's position *vis-à-vis* the foreign firm.

In a duopoly model with demand uncertainty, Klemperer and Meyer (1986, KM hereafter) show that firms are not indifferent between quantity and price setting: The dominant strategy is to choose quantity (price) if the cost curve is convex (concave). Therefore, depending on the firms' cost structures, the equilibrium market conduct could be Cournot, Bertrand, or asymmetric competition (i.e., one sets a quantity while the other sets a price).

The present study extends the BS model by introducing demand uncertainty, exploring nonlinear policies, and examining firms' choices of strategic variables. In particular, I propose a nonlinear export subsidy scheme and demonstrate that this policy is strictly superior to the often-studied linear scheme. The fundamental reason is quite simple. Both nonlinear and linear schemes can place the domestic firm in the Stackelberg leader's position *given* a particular market conduct; but, in addition to that, the former can change the market conduct in favor of the domestic firm, giving the domestic firm a strategic advantage in competition. Nonlinear export policies, in which the subsidy per unit of export is not constant, are in fact practical. An *ad valorem* subsidy can be viewed as a nonlinear specific subsidy because when the former is converted to the latter, the specific subsidy rate varies as export volume changes.[3] In the late 1980s, to encourage exports the Chinese government subsidized firms by 3 yuan (about US$0.64 during that period) for every US$100 exports if their total exports were below a certain level but, if above, they could receive 10 yuan (about US$2.13) for every US$100 exports (see Yu, 1992).

The paper most related to the present one is Laussel, who generalizes the BS model by allowing firms to choose supply functions. Optimal government intervention, then, is to induce the firms to choose steeper supply functions. By doing so, competition is softened and therefore both the domestic and foreign firms' profits are increased. Unlike Laussel, I focus on price and quantity setting behaviour, and hence reach somewhat different conclusions. In particular, a nonlinear policy may give the domestic firm a *strategic advantage* over the foreign firm. The supply function approach, however, adds flexibility not only to the domestic firm but also to the foreign firm. Thus, the strategic advantage which could otherwise be obtained by the domestic firm disappears in Laussel.[4] Moreover, I consider nonconstant marginal costs and therefore am able to link an optimal subsidy scheme to the cost structure, given a fixed degree of demand uncertainty. In contrast, under constant marginal costs, Laussel stresses the link between an optimal linear-quadratic schedule and the degree of uncertainty.

The remainder of the paper is organized as follows. In Section 2, I develop a model for analysis. In Section 3, optimal linear and optimal quadratic schemes are derived, and by comparison I reach the conclusion that the former is superior to the latter. Section 4 explores a more general scheme, i.e., a linear-quadratic combination. Section 5 concludes the paper.

2. The Model

As in BS, there are two firms, one domestic and one foreign, producing and selling differentiated products to a third country. Unlike the earlier model, however, demand is uncertain. Moreover, the domestic government, which is the only government assumed to be involved, is not confined to linear policies.

As in KM, demand is characterized by a linear system:

$$p_i = a - bq_i - dq_j + \epsilon \quad i,j = H,F, \quad i \neq j, \quad a > 0, \quad b \geq d \geq 0, \tag{1}$$

where q_H and q_F denote the domestic and foreign firms' output, respectively, p_H and p_F are the corresponding prices, and ϵ stands for a random shock. $E(\epsilon) = 0$ and $E(\epsilon^2) = \sigma^2 > 0$. (1) can be rewritten in the following way:

$$p_i = \alpha + \gamma p_j - \beta q_i + (1-\gamma)\epsilon, \quad i,j = H,F, \quad i \neq j, \tag{2}$$

where $\alpha \equiv a(b-d)/b, \beta \equiv (b^2 - d^2)/b$, and $\gamma \equiv d/b$.

Also assume that firms have identical cost structures: $C(q) = c_1 q + c_2 q^2/2$, where $0 < c_1 < a$ and c_2 can be positive or negative. Although my analysis is based on the assumption of linear demand and linear-quadratic cost, it is not difficult to see that the qualitative results obtained shall remain valid in a more general setting.

The model can be viewed as a two-stage game. In the first stage, the domestic government determines and announces its export subsidy, which is a function of the domestic firm's output (export). In particular, a policy takes the following form, called a linear-quadratic scheme,

$$S(q_H) = s_1 q_H + s_2 q_H^2/2. \tag{3}$$

The next section, however, focuses on the two special cases of this general policy, i.e., a linear scheme (when $s_2 = 0$) and a quadratic scheme (when $s_1 = 0$).

In the second stage, firms make their decisions simultaneously. A decision is an *ex anti* commitment to price or output. A commitment to price means that a firm fixes its price prior to demand uncertainty being resolved and then (i.e., after uncertainty is resolved) produces the amount equal to the actual (*ex post*) demand. Similarly, when a firm makes a commitment to output, it produces a certain amount of output prior to demand uncertainty being resolved and then sells all products at the price which clears the *ex post* market. In the first case, the firm chooses price as a strategic variable, while in the last case its strategic variable is quantity.

Thus, given subsidy $S(q_H)$, the domestic firm's profit function is $\pi_H = p_H q_H - C(q_H) + S(q_H)$, and the foreign firm's is $\pi_F = p_F q_F - C(q_F)$. The government selects a policy to maximize the domestic country's expected welfare, which is equal to the domestic firm's expected profit net subsidy: $W = E[p_H q_H - C(q_H)]$.

3. Linear vs. Quadratic Schemes

Our setting is similar to KM except the presence of a government in our model. In this section, we first derive a useful result for the general linear-quadratic policy. The main part of this section then is devoted to derivation and comparison of optimal linear and optimal quadratic schemes. Analysis about the optimal linear-quadratic scheme will be conducted in Section 4.

Given the first-stage policy levels, s_1 and s_2, in the second stage each firm maximizes its profit choosing a strategic variable and a value for the chosen variable simultaneously, based on the conjecture that its rival's choices (i.e., for both the type of strategic variable and its value) are constant. Thus, from the demand system we note that, given any action taken by the foreign firm, the domestic firm faces a residual demand:

$$p_H = A_H - B_H q_H + \lambda_H \epsilon$$

where $A_H = a - dq_F$, $B_H = b$, and $\lambda_H = 1$ if the foreign firm sets a quantity [from (1)], but $A_H = \alpha + \gamma p_F$, $B_H = \beta$, and $\lambda_H = (1-\gamma)$ if the foreign firm sets a price [from (2)]. The foreign firm's residual demand, $p_F = A_F - B_F q_F + \lambda_F \epsilon$, is defined in a similar way.

Now we state our first result. The proof is similar to that in KM. **Lemma.** Given export policy $S(q_H)$ as defined in *(3)*,

(i) the domestic firm's optimal choice is to set quantity (price) if $c_2 \geq (<) s_2$;

(ii) the foreign firm's optimal choice is to set quantity (price) if $c_2 \geq (<) 0$.

The implications of Lemma 1 are straightforward. First, a firm's optimal choice of strategic variables is independent of its rival's choice. Second, a firm selects a strategic variable according to the slope of its perceived marginal cost (i.e., production cost net subsidy) curve. The intuition behind this, as provided by KM, is that for convex (concave) costs, a fixed level of output is more (less) attractive than a random level with the same mean.

What is new and more important here is that a nonlinear policy (i.e., $s_2 \neq 0$) can *alter* the slope of the domestic firm's perceived marginal cost curve and therefore affect the domestic firm's choice of strategic variables,[5] but a linear scheme cannot. Later on we shall show that such a difference makes a nonlinear scheme strictly superior to a linear one.

For later analysis, we derive here the domestic country's welfare:

$$W(s_1, s_2) = \Phi/2(2B_H + c_2 - s_2)^2 - x\sigma^2 c_2/2B_H^2, \tag{4}$$

where $\Phi \equiv [(A_H - c_1)^2 - s_1^2](2B_H + c_2 - s_2) - s_2(A_H - c_1 + s_1)^2$, $x = 0$ if $c_2 \geq s_2$, and $x = \lambda_H^2$ if $c_2 < s_2$. It is obtained by substituting the domestic firm's optimal choice into W, given policy parameters and the foreign firm's choice.

Linear Scheme

Since a linear policy has no effect on either firm's choice of strategic variables, the second-stage market conduct simply depends on the slope of the marginal cost curve. We now investigate the two possibilities: $c_2 \geq 0$ and $c_2 < 0$.

(i): $c_2 \geq 0$. By Lemma 1, both firms will set quantities and therefore the second-stage market competition is characterized by a Cournot game. Thus, given s_1, the domestic firm chooses q_H to maximize its expected profit $E\pi_H$, taking q_F as constant. From the first-order condition we get its reaction function $q_H = (a - c_1 + s_1 - dq_F)/k$, where $k \equiv 2b + c_2$. Similarly, the foreign firm's reaction function is $q_F = (q - c_1 - dq_H)/k$. Hence, given s_1, the equilibrium quantities are, letting $z \equiv (k - d)(a - c_1)$,

$$q_H^* = (z + ks_1)/(k^2 - d^2) \quad \text{and} \quad q_F^* = (z - ds_1)/(k^2 - d^2). \tag{5}$$

Thus, from (4), we obtain

$$W(s_1) = [(a - dq_F^* - c_1)^2 - s_1^2]/2k, \tag{6}$$

where q_F^* is given in (5). Therefore, the optimal subsidy rate is

$$s_1^c = d^2 z/k(k^2 - 2d^2) > 0. \tag{7}$$

(ii): $c_2 < 0$. In this case, firms set prices and hence the second-stage competition is a Bertrand game. Given s_1 and using (2), we can derive the equilibrium prices and then using (4), we obtain

$$W(s_1) = [(\alpha + \gamma p_2^* - c_1)^2 - s_1^2]/2h - (1 - \gamma)^2\sigma^2 c_2/2\beta^2, \tag{8}$$

where $p_F^* = [\alpha(\beta + c_2) + \beta c_1]/D_1 - \beta\gamma(\beta + c_2)s_1/D_2$, $h \equiv 2\beta + c_2, D_1 \equiv h - (\beta + c_2)\gamma$, and $D_2 \equiv h^2 - (\beta + c_2)^2\gamma^2$. We assume $\beta + c_2 > 0$ to avoid downward sloping reaction curves in Bertrand competition. The optimal subsidy is

$$s_1^b = -\beta\gamma^2(a - c_1)(1 - \gamma)(\beta + c_2)D_3/D_4D_5 < 0, \tag{9}$$

where $D_3 \equiv h + (\beta + c_2)\gamma, D_4 \equiv h - (\beta + c_2)\gamma^2$, and $D_5 \equiv h^2 - (\beta + c_2)\gamma^2 c_2$.

Quadratic Scheme

As in the linear case, we now derive the optimal quadratic scheme in two cases: upward sloping and downward sloping marginal cost curves.

(i): $c_2 \geq 0$. According to Lemma 1, the foreign firm will set a quantity. The domestic firm's choice, however, depends on s_2. In the following analysis, we shall first divide all possible policy levels into two regions such that in each region the domestic firm's choice of strategic variables remains unchanged. Then we derive the firms' optimal responses within each region. Finally, to obtain the optimal policy, we make a welfare comparison between these two regions.

Suppose that the government confines its policy level to $s_2 \leq c_2$. By Lemma 1, the resulting market conduct follows Cournot. Deriving and substituting the equilibrium quantities to the welfare function (4) yields

$$W(s_2) = (a - c_1 - dq_F^*)^2(k - 2s_2)/2(k - s_2)^2 \tag{10}$$

where $q_F^* = [z - (a - c_1)s_2]/[(k - s_2)k - d^2]$. The government chooses s_2 to maximize $W(s_2)$, subject to $s_2 \leq c_2$. The optimal export subsidy rate is

$$s_2^c = \begin{cases} d^2/k & \text{if } d^2 \leq kc_2 \\ c_2 & \text{otherwise.} \end{cases} \tag{11}$$

Now suppose that the government's policy level is restricted to $s_2 > c_2$. Then the market competition is characterized by an asymmetric game, with the domestic firm setting a price and the foreign firm setting a quantity. We refer to this as (p,q) competition, where the first element in the parenthesis stands for the domestic firm's strategy and the second for the foreign firm's strategy. Similar to the derivation of Cournot-Nash and Bertrand-Nash equilibria, we calculate the market equilibrium for (p,q) competition, p_H^* and q_F^*, and then substitute in (4) to obtain

$$W(s_2) = (a - c_1 - dq_F^*)^2(k - 2s_2)/2(k - s_2)^2 - \sigma^2 c_2/2b^2h^2, \tag{12}$$

where $q_F^* = [z-(a-c_1)s_2]/[(k-s_2)(k-d\gamma)-d^2]$. The government maximizes $W(s_2)$ by choice of s_2, subject to $c_2 < s_2$. The solution to this constrained maximization is

$$s_2^{pq} = \begin{cases} d^2/(k-d\gamma) & \text{if } d^2 > (k-d\gamma)c_2 \\ c_2 & \text{otherwise.} \end{cases} \tag{13}$$

Now we are ready to compare the two local optimums. To make the comparison relevant and interesting, we focus on their interior solutions. From (10) and (11), we obtain the welfare in Cournot competition

$$W_Q^c = z^2/2k(k^2-2d^2). \tag{14}$$

Also (12) and (13) together give the welfare in (p,q) competition

$$W_Q^{pq} = \omega - \sigma^2 c_2/2b^2h^2, \tag{15}$$

where $\omega \equiv (a-c_1)^2(k-d-d\gamma)^2/2(k-d\gamma)[k(k-d\gamma)-2d^2]$. Comparing W_Q^c and W_Q^{pq} yields the following result.

Lemma 1. *If $c_2 \geq 0$ and $d^2 \leq (2b+c_2)c_2$, then $W_Q^c > W_Q^{pq}$. Thus, s_2^c defined in (11) is an optimal quadratic policy for $c_2 \geq 0$ and therefore the equilibrium market conduct is Cournot competition.*

Proof. See Appendix (A).

Now we provide the intuition behind this result. It is well known in the strategic trade literature that an optimal strategic trade policy places the domestic firm in a Stackelberg leader's position *vis-à-vis* the foreign firm (see BS). Thus, in the following discussion, we could legitimately treat the domestic firm as a Stackelberg leader without the government. Also we ignore the uncertainty element for the moment. In quantity competition, the foreign firm faces the residual demand: $p_F = a - dq_H - bq_F$. However, in (p,q) competition, the residual demand is $p_F = \alpha + \gamma p_H - \beta q_F$. Note the foreign firm has a flatter residual demand curve in (p,q) competition than in quantity competition since $\beta < b$. It implies that the adverse effect of increasing output by the foreign firm on its own price is smaller in the case of (p,q) competition, and therefore the firm will set a higher output level in (p,q) competition than in quantity competition. Therefore, by setting quantity, the domestic firm indirectly forces the foreign firm to act less aggressively (i.e., selling less to the market). This is the *strategic advantage* of quantity setting.[6]

(ii): $c_2 < 0$. By Lemma 1, the foreign firm will set a price, but the domestic firm's choice depends on the policy level. As before, we should examine the two possible types of market conduct separately.

If $s_2 > c_2$, the domestic firm also sets a price and the second stage is a Bertrand game. Consequently, the expected welfare function becomes

$$W(s_2) = (\alpha - c_1 + \gamma p_F^*)^2(h - 2s_2)/2(h - s_2)^2 - (1-\gamma)^2\sigma^2 c_2/2\beta^2, \tag{16}$$

where $p_F^* = [(\alpha\beta + \alpha c_2 + \beta c_1)(D_3 - s_2) - \alpha\gamma(\beta + c_2)s_2]/[(h - s_2)D_4 + \beta\gamma^2(\beta + c_2)]$. The government chooses s_2 to maximize $W(s_2)$, subject to $c_2 < s_2 < h$, where the second inequality is imposed to meet the second-order condition. The solution to this constrained maximization problem defines the policy level in Bertrand competition:

$$s_2^b = \begin{cases} -d\gamma(b + c_2 - d\gamma)/(k - d\gamma) & \text{if } \gamma^2(1-\gamma^2) < -kc_2/b^2 \\ c_2 & \text{otherwise.} \end{cases} \tag{17}$$

Now consider the case for $s_2 \le c_2$. By Lemma 1, the second stage of the game is (q,p) competition, i.e., the domestic firm sets a quantity while the foreign firm sets a price. The expected welfare is

$$W(s_2) = (\alpha - c_1 + \gamma p_F^*)^2(h - 2s_2)/2(h - s_2)^2, \tag{18}$$

where $p_F^* = [(h - s_2)(ab + ac_2 + bc_1) - d(b + c_2)(\alpha - c_1)]/[k(h - s_2) + d\gamma(b + c_2)]$. Then the optimal export subsidy rate in (q,p) competition is

$$s_2^{qp} = \begin{cases} -d^2(b + c_2)/bk & \text{if } d^2 \ge -kbc_2/(b + c_2) \\ c_2 & \text{otherwise.} \end{cases} \tag{19}$$

From (16) and (17), we obtain the optimal welfare in Bertrand competition

$$W_Q^b = \omega - (1-\gamma)^2\sigma^2 c_2/2\beta^2. \tag{20}$$

Let W_Q^{qp} denote the optimal welfare in (q,p) competition, obtained from (18) and (19). We find that it is identical in form to Q_Q^c in (14). Through comparison [see Appendix (B)], we establish the following result.

Lemma 2. If $c_2 < 0$, $d^2 > -(2b + c_2)bc_2/(b + c_2)$, and σ is not too large, then $W_Q^{qp} > W_Q^b$. The optimal policy, s_2^{qp} defined in *(19)*, induces the domestic firm to choose quantity as its strategic variable. As a result, the market conduct is (quantity, price) competition.

As mentioned before (immediately after Lemma 2), the domestic country achieves a strategic advantage by inducing the domestic firm to use quantity setting. If, however, the marginal cost curve is downward sloping, price setting has benefits. Thus, there exists a trade-off between quantity setting and price setting. The restriction which Lemma 3 puts on the random shock is critical for resolving the trade-off. If the random shock is very big, price setting should dominate the firm's strategy.

(iii): Summary. Now we conclude from the above analysis.

Proposition 1. *If $d^2 \leq (2b+c_2)c_2$ when $c_2 \geq 0$, or $d^2 > -(2b+c_2)bc_2/(b+c_2)$ and σ is not too big when $c_2 < 0$, an optimal quadratic scheme will support the domestic firm in choosing (when $c_2 \geq 0$) or induce it to choose (when $c_2 < 0$) quantity as the strategic variable. More specifically, an optimal quadratic scheme is $S(q_H) = s_2^* q_H^2/2$ where*

$$s_2^* = \begin{cases} d^2/(2b+c_2) > 0 & \text{if } c_2 \geq 0 \\ -d^2(b+c_2)/b(2b+c_2) < 0 & \text{if } c_2 < 0. \end{cases} \tag{21}$$

The equilibrium market conduct is Cournot competition when $c_2 \geq 0$, and (quantity, price) competition when $c_2 < 0$. The domestic country's expected welfare under this scheme is

$$W_Q^* = (a-c_1)^2(2b+c_2-d)^2/2(2b+c_2)[(2b+c_2)^2-2d^2). \tag{22}$$

Proof. See Appendix (C).

It is worth stressing that while Lemma 1 indicates the government's ability to manipulate the domestic firm's choice of strategic variables, Proposition 1 shows the desire for such manipulation.

Scheme Comparison

The maximum welfare under the quadratic scheme is given by (22) . In order to make welfare comparison, we calculate the maximum welfare under the linear scheme.

Substituting q_F^* given by (5) and s_1^c defined in (7) into (6) yields the maximum welfare under the linear scheme for the case of $c_2 \geq 0$: $W_L^c = z^2/2k(k^2-2d^2)$, which is identical to W_Q^*. Despite their differences, the two policies generate the same welfare for the domestic country. This is not surprising since firms compete in quantities under both schemes and both schemes induce the domestic firm to choose the Stackelberg leader's output.

Let W_L^b denote the maximum welfare under the linear scheme when $c_2 < 0$, which can be obtained from (8) and (9). We can show that $W_L^b = W_Q^b$. Note, when $c_2 < 0$, $W_Q^* = W_Q^{qp}$. Thus, by Lemma 3 and Proposition 1, It follows that $W_Q^* > W_L^b$. That is, the quadratic scheme generates higher welfare for the domestic country than the linear scheme. We now summarize the above discussion. Let W_L^* denote the maximum welfare under a linear scheme.

Proposition 2. *Under the restrictions stated in Proposition 1, quadratic schemes are strictly superior to linear schemes. More precisely,* $W_Q^* > (=) W_L^*$ *when* $c_2 < (\geq) 0$.

When the strategic advantage of quantity setting prevails, a quadratic scheme enables the domestic firm to commit to setting quantities. A Linear scheme, in contrast, cannot alter the curvature of the firm's perceived marginal costs and so cannot induce the firm to adopt a quantity strategy. Due to this difference, a quadratic scheme is preferred to a linear one.

The superiority of a nonlinear scheme in Laussel is due to its ability to soften the market competition, by inducing both the domestic and foreign firm to choose steeper supply curves. Although firms in my model are less flexible (they choose price or quantity but not supply curve) to adapt to the uncertain environment, a quadratic scheme gives the domestic firm unique flexibility in choosing price and quantity, and thus the domestic firm can enjoy the strategic advantage in the case of (quantity, price) competition, which puts the foreign firm in the worst situation (see Singh and Vives, 1984). This, however, never occurs in Laussel.

4. Linear-Quadratic Scheme

From the sufficient conditions stated in Propositions 1 and 2, we note that the superiority of a quadratic scheme over a linear one rests on two conditions relating to the steepness of marginal costs (c_2) and the degree of demand uncertainty (σ). To understand the importance of these conditions and how to relax them, let us first derive an optimal linear-quadratic scheme. Theoretically, we can still use the method of backward induction to obtain the optimal policy. Practically, however, this method is extremely difficult. Alternatively, in the following analysis, we first assume that in the absence of government, the domestic firm is the Stackelberg leader and the foreign firm is the follower in all types of market competition; we then derive the leader's optimal strategy; next, we come back to our original (simultaneous movement) game with the government using linear-quadratic policy; finally, by choosing the policy parameters such that the domestic firm's strategy in the latter case coincides with that of the Stackelberg leader, we obtain an optimal policy.[7]

In the absence of government, suppose the domestic firm is a Stackelberg leader and sets quantity, q_H. If the foreign firm sets quantity, its reaction function and expected profit are, respectively,

$$q_F = (a - c_1 - dq_H)/k \quad \text{and} \quad E\pi_F^{qq} = (a - c_1 - dq_H)^2/2k. \tag{23}$$

If, however, it sets price, the expected profit is $E\pi_F^{qp} = E\pi_F^{qq} - c_2\sigma^2/2b^2$.

Suppose the domestic firm sets price, p_H. Then if the foreign firm sets quantity, its reaction function and expected profit are given by

$$q_F = (\alpha - c_1 + \gamma p_H)/h \quad \text{and} \quad E\pi_F^{pq} = (\alpha - c_1 + \gamma p_H)^2/2h. \tag{24}$$

But if it sets price, the expected profit is $E\pi_F^{pq} = E\pi_F^{pq} - (1-\gamma)^2 c_2\sigma^2/2\beta^2$.

Therefore, by comparison, the follower will set quantity if and only if $c_2 \geq 0$, independent of the leader's choice.

Now we switch to consideration of the leader's decision. Suppose $c_2 \geq 0$. The domestic firm realizes that the foreign firm's reaction is given by either (23) or (24). After some calculation, we can obtain the domestic firm's optimal expected profit. If it chooses quantity, it will set

$$q_H^* = (a - c_1)(k - d)/(k^2 - 2d^2), \tag{25}$$

and the resulting profit is identical to that given in (14). If it selects price, (15) is its profit. It immediately follows, from Lemma 2, that the leader will set quantity if $c_2 \geq 0$. This result holds *unconditionally.*

Now suppose $c_2 < 0$. By solving the leader's optimization problems, we note that if it sets quantity, the formula is also given by (25) and the profit is identical, in form, to that given in (14), but if it sets price, the profit is equal to that in (20). Thus, the leader will set quantity if and only if σ is not too big (see the proof of Lemma 3). Note in particular that the constraint on c_2 in Lemma 3 is no longer required here.

We now turn to the case with policy. First, $c_2 \geq 0$. If $s_2 \leq c_2$, then it can be checked that the domestic firm's optimal choice in the second-stage game is to set $q_H^* = (z + ks_1)/[k(k - s_2) - d^2]$, which will be identical to (25) when

$$s_1 = d^2 z/k(k^2 - 2d^2) \quad \text{and} \quad s_2 = 0. \tag{26}$$

Second, $c_2 < 0$. If σ is not too big, the government should choose $s_2 \leq c_2$ so that the domestic firm sets quantity. Routine calculation yields $q_H^* = (z + ks_1)/[k(k - s_2) + d\gamma(b + c_2)]$, which is equal to the Stackelberg leader's quantity, (25), when

$$s_1 = z[k(d\gamma - c_2) + d^2]/k(k^2 - 2d^2) \quad \text{and} \quad s_2 = c_2. \tag{27}$$

We have established the following result.

Proposition 3. If $c_2 \geq 0$, *(26) is an optimal linear-quadratic policy. If* $c_2 < 0$ *and* σ *is not too big, (27)* is *an optimal linear-quadratic policy. The domestic firm sets quantity in both cases.*

The sharp difference between Propositions 2 and 3 is the absence of restrictions on c_2 in the latter. Note, when quantity setting is desirable, any general optimal policy is required to serve two purposes: (i) to induce the domestic firm to set quantity, and (ii) to place the firm in a Stackelberg leader's position. A linear policy can never be an optimal one when the domestic firm's strategic variable selection needs to be altered (i.e., when $c_2 < 0$). Although a pure quadratic scheme is able to affect the domestic firm's choice of strategic variable, its single policy parameter (s_2) sometimes fails to achieve the two goals at the same time, i.e., the level required to put the domestic firm in the leader's position may be too high to keep the firm from switching to price setting (i.e., $s_2 > c_2$), or the constraint on s_2 to maintain quantity setting may make the policy level insufficient to achieve the second goal. Such a conflict does not exist in a linear-quadratic scheme since it has two policy parameters, each assuming different responsibilities. The linear part (s_1) helps serve the second purpose while the quadratic part (s_2) is only responsible for the first task.

Both propositions impose conditions on σ. This is because when uncertainty is high, the benefit from having a fixed price outweighs the strategic advantage of quantity setting.

5. Conclusion

When demand uncertainty and nonconstant marginal costs are present in a model of international duopoly, firms have strict preferences in the choice of strategic variables, namely quantity and price. A nonlinear policy can influence the domestic firm's preference and thereby can shift the equilibrium market conduct in favor of the domestic country. The often-studied linear policy lacks such capability, and is, therefore, strictly inferior to a nonlinear policy.

The present study can be extended to consider the case in which the government of the importing country attempts to protect its consumers via its trade policies. Although the existing literature on optimal import policy is sizable, our approach would be very different. We are interested in an import policy which has the ability to influence the exporters' strategic variable selection. This issue is important as consumers are affected differently by different types of competition among exporters.

Appendix

A. Proof of Lemma 2 :

Let $d_1 \equiv \sqrt{(k-d\gamma)c_2}$ and $d_2 \equiv \sqrt{kc_2}$. If the domestic firm sets price regardless of s_2, then the optimal welfare, denoted as W_u^{pq}, is equal to that given in (15) even for $d \leq d_1$. Thus, $W_u^{pq} \geq W_Q^{pq}$ for $d \leq d_1$ since W_u^{pq} is an unconstrained optimum while W_Q^{pq} is a constrained one. Note $W_u^{pq} = W_Q^{pq}$ for $d > d_1$. It remains to show $W_Q^c > W_u^{pq}$.

Define $g(y) = (k-d-y)^2/(k-y)[k(k-y)-2d^2]$ for $y \leq d$. Then, $W_Q^c - W_u^{pq} > (a-c_1)^2[g(0)-g(d\gamma)]/2$. Since $\partial g(y)/\partial y < 0$, $g(0) > g(d\gamma)$. The result follows. □

B. Proof of Lemma 3 :

The proof is the same as that of Lemma 2. Because W_Q^b equals ω plus a positive term while W_Q^{pq} equals ω plus a negative term, the condition that σ is not too big is necessary here but not in Lemma 2. □

C. Proof of Proposition 1 :

(21) is an immediate result of Lemmas 2 and 3, (11), and (19). (22) follows from (14) and that W_Q^{qp} is identical to W_Q^c in form. □

References

Brander, J. A. and B. J. Spencer, "Export Subsidies and International Market Share Rivalry," *Journal of International Economics* 18 (1985): 83-100.

Dixit, A. K., "Optimal Trade and Industrial Policies for the US Automobile Industry," in R.C. Feenstra (ed.), *Empirical Methods for International Trade*, Cambridge, MA: MIT Press, 1988, pp. 141-65.

Eaton, J. and G. Grossman, "Optimal Trade and Industrial Policy under Oligopoly," *Quarterly Journal of Economics* 101 (1986): 383-406.

Helpman, E. and P. R. Krugman, *Trade Policy and Market Structure*, Cambridge, MA: MIT Press, 1989.

Klemperer, P. and M. Meyer, "Price Competition vs. Quantity Competition: The Role of Uncertainty," *Rand Journal of Economics* 17(4) (1986): 618-38.

Laussel, D., "Strategic Commercial Policy Revisited: A Supply-Function Equilibrium Model," *American Economic Review* 82(1) (1992): 84-99.

Qiu, L. D., "Three Essays on Strategic Trade Policies," Ph.D. dissertation, University of British Columbia, 1993.

Singh, N. and X. Vives, "Price and Quantity Competition in a Differentiated Duopoly," *Rand Journal of Economics* 15(4) (1984): 546-54.

Yu, H. S., *Handbook of Foreign Trade and Law*, (in Chinese), The Law Publishing Co., 1992.

Endnotes

1. For a literature survey, see Helpman and Krugman (1989) among others.

2. Although in the empirical study of optimal trade and industrial policies for the US automobile industry Dixit (1988) has expressed the concern that equilibrium conjecture variations might be functions of trade policies, he did not take this approach in his analysis.

3. $S = (1 + s)pq$, where p and q are price and volume of export, is an *ad valorem* subsidy policy. In this case, the specific subsidy rate is $(1 + s)p$, which is a function of q.

4. The (quantity, price) competition, which puts the domestic firm in the best strategic position, is a possible result in the present model but never a case in Laussel.

5. In Laussel, supply functions are strategic complements and the domestic government's policy influences the slope of *both* firms' supply functions. In our model, however, government policy is incapable of affecting the foreign firm's strategy choice.

6. Such a strategic advantage has also been identified by Singh and Vives (1984) in their two-stage game, in which each firm commits to a strategy in the first stage and then, in the second stage, sets a value for the chosen strategic variable.

7. This has been suggested by the referee.