HKIBS/WPS/004-967
December 1996

Endogenous Sequencing in Strategic Trade Policy Games under Uncertainty

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Abstract

This paper examines a trade policy game with endogenous timing. A trade-off between commitment and flexibility is identified. The timing of trade policy decisions is shown to depend on the degree of demand uncertainty. When demand uncertainty is low, countervailing duties will never be used because the home government sets its tariff first followed by the export subsidy of the foreign government. When demand uncertainty is very high, the foreign government sets its subsidy first followed by the tariff set by the home government. The foreign government actually imposes an export tax anticipating the tariff retaliation of home government to any export subsidy. Finally, when demand is moderately volatile, countervailing duties will be used with positive probability.

The fundamental basis of countervailing duties is simple and straightforward: When unfair trade is created by the fact that exports are being subsidized, countervailing duties are designed to compensate for the unfair edge provided by export subsidies. The General Agreement on Tariffs and Trade (GATT) has long recognized the right of countries to act unilaterally to counter imports priced at 'less than their normal values'. Article VI of the GATT allows countries to offset injurious dumping by imposing antidumping or countervailing duties. Schott (1994) reports that antidumping cases have become the preferred channel of import-competing industries to petition for protection against foreign suppliers. In the early 1960s, the GATT member countries (in total) undertook fewer than a dozen cases per year. Between 1985 and 1992, however, more than 1000 cases were initiated and more than 40 countries now have antidumping/countervailing duty laws in place (Schottt 1994, p. 78). Such a widespread use of antidumping/countervailing measures has attracted a lot of attention in the international trade literature. In the area of export subsidies and countervailing duties, Dixit (1988) and Collie (1991) have shown that the optimal domestic response to a foreign export subsidy is to retaliate with a partial countervailing tariff. They further point out that in oligopolistic industries retaliation cannot undercut the argument of profit shifting from domestic to foreign firms *à la* Brander and Spencer (1985).

Much of the literature of strategic trade policy treats the sequence of moves of rival governments as exogenously given. For example, Collie (1991) examines the optimal export subsidy set by a foreign government when a home government responds to a foreign export subsidy with a home import tariff. In his model, as such, the foreign government is exogenously assigned the role of a Stackelberg leader and the home government the role of a Stackelberg follower.[1] To remedy this modelling drawback, Collie (1994) extends his earlier work by allowing the timing of trade policy decisions to be endogenous. He shows that the unique equilibrium sequence of moves of the rival governments is that the home government announces its trade policy before the foreign government does. The underlying intuition is that there is a strategic commitment value should the rival governments adopt this sequence of moves: The home government can commit itself not to retaliate by moving first and this in turn induces the foreign government to offer a larger export subsidy. An immediate conclusion is that imperfect competition cannot explain the existence of countervailing duties since the home government should commit not to use them in equilibrium.

In reality, we do see countervailing duties put in use quite often. The purpose of this paper is to show that uncertainty in the economic environment, which is absent in Collie's (1994) framework, may be a key factor that rationalizes the use of countervailing duties in practice. We introduce uncertainty into Collie's (1994) framework by means of an additive random demand shock. Flexibility is modelled as a choice by each government to announce its trade policy prior to or subsequent to the realization of the random demand shock. As a result, each government is endowed with an option to wait which can be exercised prematurely should the government announce its trade policy before the demand uncertainty is resolved. Of course, exercising the option prematurely prevents the government from manipulating the oligopoly outcome for its national benefits when new information arrives. Consequently, a trade-off between commitment and flexibility exists in this strategic trade policy game under uncertainty.

This paper shows that the equilibrium sequence of moves of the rival governments highly depends on the volatility of the random demand shock. When the demand uncertainty is low, the unique equilibrium is the one in which the home government chooses its import tariff prior to the resolution of the uncertain demand condition, while the foreign government chooses its export subsidy after observing the realization of the random demand shock. This is consistent with the finding in Collie (1994) as his model is a special case of ours with no demand uncertainty. However, when the demand uncertainty is sufficiently high, the unique equilibrium turns out to be the one in which the home government will move second with positive probability (the mixed-strategy equilibrium) or for sure (the pure-strategy equilibrium) depending on whether the random demand shock is moderately volatile or extremely volatile, respectively. To wit, as long as the volatility of the random demand shock reaches a threshold level, countervailing duties are triggered to be used by the home government. The underlying intuition is that the option value of waiting increases with the degree of uncertainty so that there is a threshold level of uncertainty above which the advantage of commitment to the home country no longer outweighs the disadvantage of inflexibility. In a sense, we provide an economic rationale for countervailing duties when competition is imperfect and demand condition is sufficiently uncertain. It is the trade-off between commitment and flexibility that makes countervailing duties possible.

The remaining parts of this paper are organized as follows. The next section presents the basic structure of a strategic trade policy game under demand uncertainty. Section 2 characterizes the equilibrium sequence of moves of the rival governments in the absence of the demand uncertainty. Section 3 looks at the equilibrium sequence of moves of the rival governments when the demand uncertainty resumes and shows how this timing decision is sensitive to the degree of the demand uncertainty. The final section provides some concluding remarks.

1. The model

Consider two countries, labelled home (H) and foreign (F), each of which has one firm producing a single homogeneous good. The home firm produces output q_H at a constant marginal cost c_H, whereas the foreign firm produces output q_F at a constant marginal cost c_F. The home and foreign firms compete as Cournot quantity-setters in the home market. The inverse demand function is given by $P(Q) + \tilde{\theta}$, where $Q = q_H + q_F$, P is the expected price of the good, and $\tilde{\theta}$ is an additive random demand shock with mean zero and variance σ^2. We assume that the expected demand function is downward-sloping (i.e, $P' < 0$) and each firm's expected marginal revenue is a decreasing and weakly concave function of its rival's output (i.e., $P' + P''q_i < 0$ and $P'' + P'''q_i \leq 0$ for $i = H$ and F).

The set-up is a three-stage game in which the demand uncertainty is completely resolved at the end of the first stage. To begin with, the home and foreign governments simultaneously decide whether to publicly announce their trade policies before or after $\tilde{\theta}$ is revealed. That is, both governments simultaneously decide whether to publicly announce their trade policies in stage one or in stage two. The trade policy instrument used by the foreign government is a subsidy, s, paid to the foreign firm for each unit of exports. The home government, on the other hand, uses a tariff, t, imposed on each unit of imports. In the second stage, the demand uncertainty is completely resolved and the government which decided to delay its trade policy choice can now make its announcement. In the final stage, the home and foreign firms, knowing the realization of $\tilde{\theta}$, engage in Cournot competition in the home market.

Given the trade policies, s and t, and the realized demand shock, $\tilde{\theta} = \theta$, the profits of the home and foreign firms are, respectively,

$$\pi_H(s,t,\theta) = (P + \theta - c_H)q_H,$$

$$\pi_F(s,t,\theta) = (P + \theta - c_F + s - t)q_F.$$

The Cournot-Nash equilibrium is characterized by the following pair of first-order conditions:[2]

$$P + \theta + P'q_H - c_H = 0, \tag{1}$$

$$P + \theta + P'q_F - c_F + s - t = 0. \tag{2}$$

To obtain the comparative static results for the effects of the home import tariff and the foreign export subsidy on the equilibrium outputs, we totally differentiate (1) and (2) to yield

$$\frac{\mathrm{d}q_H}{\mathrm{d}t} = -\frac{\mathrm{d}q_H}{\mathrm{d}s} = -\frac{1}{D}(P' + P''q_H) > 0, \tag{3}$$

$$\frac{\mathrm{d}q_F}{\mathrm{d}t} = -\frac{\mathrm{d}q_F}{\mathrm{d}s} = \frac{1}{D}(2P' + P''q_H) < 0, \tag{4}$$

where $D = P'(3P' + P''Q) > 0$. Thus, an increase in the home import tariff increases home production and at the same time reduces foreign exports. The opposite is true for an increase in the foreign export subsidy.

Given the trade policies, s and t, and the realized demand shock, $\tilde{\theta} = \theta$, the social welfare of the home country is the sum of consumers' surplus, the home firm's profit and the import tariff revenue, i.e.,

$$W_H(s,t,\theta) = \int_0^Q (P + \theta)\ \mathrm{d}q - (P + \theta)Q + \pi_H(s,t,\theta) + tq_F. \tag{5}$$

The social welfare of the foreign country, on the other hand, is the foreign firm's profit net of the export subsidy payment, i.e.,

$$W_F(s,t,\theta) = \pi_F(s,t,\theta) - sq_F = (P + \theta - c_F - t)q_F. \tag{6}$$

Both the home and foreign governments are risk neutral and maximize their own expected social welfare.

2. Optimal sequencing without demand uncertainty

In this section, we focus first on the benchmark case in which the demand uncertainty is absent (i.e., $\widetilde{\theta} \equiv 0$). The equilibrium concept employed is Selten's (1975) subgame perfect Nash equilibrium (SPNE). As usual, we solve the SPNE by backward induction.

Note that the equilibrium of the third-stage subgames has been fully characterized by (1) and (2) with $\theta = 0$. Now, we go back to the first stage to examine all possible subgames following the timing decisions made by the home and foreign governments. There are four of them. We denote each subgame by a pair, $(d_H, \ d_F)$, where d_H and $d_F \in \{1, \ 2\}$ are the timing decisions of the home and foreign governments, respectively. If $d_H = 1$, the home government chooses to announce its trade policy in stage one. If $d_H = 2$, the home government chooses to defer its trade policy announcement until stage two. Similar interpretations apply to d_F for the foreign government. Let $s^{(d_H,d_F)}$, $t^{(d_H,d_F)}$ and $W_i^{(d_H,d_F)}$ be the equilibrium foreign export subsidy, home import tariff and country i's social welfare in subgame $(d_H, \ d_F)$, respectively.

In the absence of the demand uncertainty, it is evident that the equilibrium outcomes in subgames (1, 1) and (2, 2) are observationally equivalent. Thus, $s^{(1,1)} =$

$s^{(2,2)}$, $t^{(1,1)} = t^{(2,2)}$ and $W_i^{(1,1)} = W_i^{(2,2)}$ for $i = H$ and F. To solve for the equilibrium in these two subgames, we have to first characterize the reaction functions of the home and foreign governments.

Looking ahead to the third-stage outcome and taking the home import tariff, t, as given, the foreign government chooses an export subsidy, s, so as to maximize the foreign welfare function (6). The first-order condition is

$$\frac{\partial W_F}{\partial s} = q_F \frac{\partial P}{\partial s} + (P - c_F - t)\frac{\partial q_F}{\partial s} = 0. \tag{7}$$

Using (2), (3) and (4), the optimal export subsidy is

$$s(t) = -\frac{P' q_F}{N}(P' + P'' q_H) > 0,$$

where $N = 2P' + P'' q_H < 0$. This is the foreign government's reaction function and its slope has the same sign as

$$\frac{\partial^2 W_F}{\partial s \partial t} = \frac{P'}{D^2 N}\{(P' + P'' q_H)[N^2 + (P'')^2 q_H q_F] + (P')^2 q_F (P'' + P''' q_H)\},$$

which is negative by the assumptions on P. Thus, $s'(t) < 0$. Note also that

$$\frac{\mathrm{d}W_F}{\mathrm{d}t} = \frac{\partial W_F}{\partial t} = q_F\left(\frac{\partial P}{\partial t} - 1\right) + (P - c_F - t)\frac{\partial q_F}{\partial t} = -q_F < 0, \tag{8}$$

where the first equality follows from the envelope theorem, and the third equality follows from (3), (4) and (7). That is, whenever the foreign government sets its export subsidy optimally, foreign welfare will be reduced given an increase in the home import tariff.

The home government's reaction function can be characterized in a similar fashion. Looking ahead to the third-stage outcome and taking the foreign export subsidy, s, as given, the home government chooses an import tariff, t, so as to maximize the home welfare function (5). The first-order condition is

$$\frac{\partial W_H}{\partial t} = q_F\left(1 - \frac{\partial P}{\partial t}\right) + (P - c_H)\frac{\partial q_H}{\partial t} + t\frac{\partial q_F}{\partial t} = 0. \tag{9}$$

Using (1), (3) and (4), the optimal import tariff is

$$t(s) = -\frac{P'}{N}[q_F(2P' + P''Q) + q_H(P' + P''q_H)] > 0.$$

This is the home government's reaction function and its slope has the same sign as

$$\frac{\partial^2 W_H}{\partial t \partial s} = -\frac{P'}{D^2 N}\{(P' + P''q_F)N^2 + (P'')^2 q_F^2 (P' + 2P''q_H)$$

$$+(P')^2 q_H (P'' + P'''q_H) + 2(P')^2 q_F (P'' + P'''q_F)$$

$$+(P' + P''q_H)[(P' + P''q_H)(P' + 2P''q_F) + P'(P' + 4P''q_F) + (P'')^2 q_H^2]\},$$

which is positive as long as P is not too convex. Thus, $t'(s) > 0$. Note also that

$$\frac{\mathrm{d}W_H}{\mathrm{d}s} = \frac{\partial W_H}{\partial s} = -q_F\frac{\partial P}{\partial s} + (P - c_H)\frac{\partial q_H}{\partial s} + t\frac{\partial q_F}{\partial s} = q_F > 0, \tag{10}$$

where the first equality follows from the envelope theorem, and the third equality follows from (3), (4) and (9). That is, whenever the home government sets its import tariff optimally, home welfare will be improved given an increase in the foreign export subsidy.

The Nash equilibrium of subgames (1, 1) and (2, 2) is the pair, $(s^{(1,1)},\ t^{(1,1)}) = (s^{(2,2)},\ t^{(2,2)})$, at which $s(t)$ and $t(s)$ intersect. This is depicted in Figure 1 as point S.

(Insert Figure 1 about here)

Now, we move to subgame $(1, 2)$ in which the home government is the Stackelberg leader and the foreign government is the Stackelberg follower. The home government chooses its import tariff so as to maximize home social welfare, taking into account how the foreign government's optimal export subsidy will be affected by the home import tariff. Totally differentiating the home welfare function (5) with respect to t and taking $s(t)$ into account yields

$$\frac{\mathrm{d}W_H}{\mathrm{d}t} = \frac{\partial W_H}{\partial t} + \frac{\partial W_H}{\partial s} s'(t).$$

Evaluating the above expression at $t^{(1,1)}$ yields

$$\left.\frac{\mathrm{d}W_H}{\mathrm{d}t}\right|_{t=t^{(1,1)}} = q_F s'(t^{(1,1)}) < 0,$$

where the equality follows from (9) and (10). By the second-order condition, we know that $t^{(1,2)} < t^{(1,1)}$. This together with (8) implies that

$$W_F^{(1,2)} > W_F^{(1,1)} = W_F^{(2,2)}. \tag{11}$$

The Nash equilibrium of this subgame is depicted in Figure 1 as point H.

Finally, we go to subgame $(2, 1)$ in which the foreign government is the Stackelberg leader and the home government is the Stackelberg follower. The foreign government chooses its export subsidy so as to maximize foreign social welfare, taking into account how the home government's optimal import tariff will be affected by the foreign export subsidy. Totally differentiating the foreign welfare function (6) with respect to s and taking $t(s)$ into account yields

$$\frac{\mathrm{d}W_F}{\mathrm{d}s} = \frac{\partial W_F}{\partial s} + \frac{\partial W_F}{\partial t} t'(s).$$

Evaluating the above expression at $s^{(1,1)}$ yields

$$\left.\frac{\mathrm{d}W_F}{\mathrm{d}s}\right|_{s=s^{(1,1)}} = -q_F t'(s^{(1,1)}) < 0,$$

where the equality follows from (7) and (8). By the second-order condition, we know that $s^{(2,1)} < s^{(1,1)}$. This together with (10) implies that

$$W_H^{(2,1)} < W_H^{(1,1)} = W_H^{(2,2)}. \tag{12}$$

The Nash equilibrium of this subgame is depicted in Figure 1 as point F.

Proposition 1. *The ranking of the social welfare among the four subgames is given by*

$$W_H^{(1,2)} > W_H^{(1,1)} = W_H^{(2,2)} > W_H^{(2,1)}, \tag{13}$$

$$W_F^{(1,2)},\ W_F^{(2,1)} > W_F^{(1,1)} = W_F^{(2,2)}. \tag{14}$$

Proof. Since the home government can always choose $t^{(1,1)}$ if it wants in subgame (1, 2), by a simple reveal preference argument we establish the first inequality in (13). The second inequality follows from (12). The inequality in (14) follows from a simple reveal preference argument and (11). □

In stage one, the rival governments simultaneously choose their timing decisions d_H and d_F. Using the results above, we can condense the three-stage extensive form game to the normal form game as illustrated in Figure 2.

(Insert Figure 2 about here)

Proposition 2. *If there is no demand uncertainty, the unique SPNE timing is the pure strategy in which $d_H = 1$ and $d_F = 2$.*

Proof. We know from (13) that $d_H = 1$ is the dominant strategy of the home government. From (14), we know that $d_F \neq d_H$ is the optimal strategy of the foreign government. Hence, the unique SPNE is the dominant-strategy equilibrium in which $d_H = 1$ and $d_F = 2$. □

Proposition 2 generalizes the results by Collie (1994) to nonlinear demand functions. To understand the intuition underlying Proposition 2, let us define the value of commitment for the home government and for the foreign government as

$$CV_H^{d_F} = W_H^{(1,d_F)} - W_H^{(2,d_F)}, \tag{15}$$

$$CV_F^{d_H} = W_F^{(d_H,1)} - W_F^{(d_H,2)}, \tag{16}$$

respectively. From Proposition 1, we know that the home government always values commitment (i.e., $CV_H^{d_F} > 0$ for $d_F = 1$ and 2) while the foreign government values commitment only when the home government chooses to defer its trade policy announcement (i.e., $CV_F^1 < 0$ and $CV_F^2 > 0$). Thus, the dominant strategy of the home government is to move first and to commit to the most advantageous position. This forces the foreign government to move second as commitment has negative value for the foreign government in this case. Hence, the unique SPNE is the dominant-strategy equilibrium.

3. Optimal sequencing with demand uncertainty

In the absence of the demand uncertainty, it is clear from the previous section that countervailing duties will not be used in equilibrium. This section looks at the effect of the demand uncertainty on the optimal sequencing chosen by the rival governments.

The analysis in this section resembles that in the previous section. The only difference comes from the existence of an option value of waiting if a government chooses to defer its trade policy announcement after the demand uncertainty is completely resolved. Let $EW_i^{(d_H,d_F)}$ be country i's equilibrium expected social welfare in subgame $(d_H,\ d_F)$. Then, for any d_F chosen by the foreign government, the expected net gain (or loss) in home welfare given that the home government chooses to defer its trade policy announcement can be decomposed into two parts:

$$EW_H^{(2,d_F)} - EW_H^{(1,d_F)} = OV_H^{d_F} - CV_H^{d_F}, \tag{17}$$

where $OV_H^{d_F}$ is the option value of waiting and $CV_H^{d_F}$ is the commitment value defined in (15) that the home government has to forgo. Similarly, for any d_H chosen by the home government, we can decompose the expected net gain (or loss) in foreign welfare given that the foreign government chooses to defer its trade policy announcement as follows:

$$EW_F^{(d_H,2)} - EW_F^{(d_H,1)} = OV_F^{d_H} - CV_F^{d_H}, \tag{18}$$

where $OV_F^{d_H}$ is the option value of waiting and $CV_F^{d_H}$ is the commitment value defined in (16) that the foreign government has to forgo. It is well-known that the value of an option is nonnegative and increases with the volatility of the underlying assets (see, e.g., Merton 1973). If there is no uncertainty, the option value vanishes.

Since $CV_H^{d_F} > 0$ which is not affected by the degree of the demand uncertainty, for sufficiently stable demand condition $OV_H^{d_F}$, albeit positive, is close to zero. Thus, $d_H = 1$ should remain the dominant strategy of the home government in this case. Moreover, we know that

$$EW_F^{(1,2)} - EW_F^{(1,1)} = OV_F^1 - CV_F^1 > 0,$$

because $OV_F^1 \geq 0$ and $CV_F^1 < 0$. These imply that $d_H = 1$ and $d_F = 2$ still constitute the unique SNPE when the demand uncertainty is trivial. However, for sufficiently uncertain demand condition, we would expect the option value of waiting dominates the commitment value (i.e., $OV_H^{d_F} > CV_H^{d_F}$) and thus $d_H = 1$ should no longer be the dominant strategy for the home government.

In general it is hard to characterize the value of an option in closed form without imposing enough structure. To verify our hunch, in the sequel we will focus on the case where the expected inverse demand function is linear. That is, $P(Q) = a - bQ$, where a and b are positive constants. The derivation of the equilibrium expected social welfare of the home and foreign countries in each subgame is straightforward and unilluminating so that it is relegated to the appendix. Figure 3 depicts the payoff matrix for this game of timing.

(Insert Figure 3 about here)

In stage one, the two governments simultaneously choose their timing decisions d_H and d_F. Comparing the equilibrium expected foreign welfare when $d_F = 1$ with that when $d_F = 2$ yields

$$EW_F^{(1,2)} - EW_F^{(1,1)} = \frac{\sigma^2}{72b} + \frac{12}{1225b}(a + 3c_H - 4c_F)^2 > 0,$$

$$EW_F^{(2,2)} - EW_F^{(2,1)} = -\frac{9}{3920b}(a + 3c_H - 4c_F)^2 < 0.$$

Thus, $OV_F^1 = \sigma^2/72b$, $OV_F^2 = 0$, $CV_F^1 = -12(a + 3c_H - 4c_F)^2/1225b$ and $CV_F^2 = 9(a + 3c_H - 4c_F)^2/3920b$. These imply that $d_F \neq d_H$ is the optimal strategy of the foreign government. Comparing the equilibrium expected home welfare when $d_H = 1$ with that when $d_H = 2$ yields

$$EW_H^{(2,1)} - EW_H^{(1,1)} = \frac{\sigma^2}{18b} - \frac{459}{39200b}(a + 3c_H - 4c_F)^2 < (>)\ 0 \quad \text{if} \quad \sigma^2 < (>)\ \overline{\sigma}^2,$$

$$EW_H^{(2,2)} - EW_H^{(1,2)} = \frac{85\sigma^2}{1568b} - \frac{1}{490b}(a + 3c_H - 4c_F)^2 < (>)\ 0 \quad \text{if} \quad \sigma^2 < (>)\ \underline{\sigma}^2,$$

where $\overline{\sigma}^2 = 4131(a + 3c_H - 4c_F)^2/19600$ and $\underline{\sigma}^2 = 16(a + 3c_H - 4c_F)^2/425$. Thus, $OV_H^1 = \sigma^2/18b$, $OV_H^2 = 85\sigma^2/1568b$, $CV_H^1 = 459(a + 3c_H - 4c_F)^2/39200b$ and $CV_H^2 = (a + 3c_H - 4c_F)^2/490b$. When $\sigma^2 \leq \underline{\sigma}^2$, $d_H = 1$ is the dominant strategy for the home government. When $\sigma^2 \geq \overline{\sigma}^2$, $d_H = 2$ is the dominant strategy for the home government. When $\underline{\sigma}^2 < \sigma^2 < \overline{\sigma}^2$, the optimal strategy of the home government is that $d_H = d_F$.

Proposition 3. (i) *When $\sigma^2 \leq \underline{\sigma}^2$, the unique SPNE timing is the pure strategy in which $d_H = 1$ and $d_F = 2$.* (ii) *When $\sigma^2 \geq \overline{\sigma}^2$, the unique SPNE timing is the pure strategy in which $d_H = 2$ and $d_F = 1$.* (iii) *When $\underline{\sigma}^2 < \sigma^2 < \overline{\sigma}^2$, the unique SPNE timing is the mixed strategy in which the home and foreign governments completely randomize their timing decisions.*

Proof. (i) When $\sigma^2 \leq \underline{\sigma}^2$, $d_H = 1$ is the dominant strategy for the home government. Given that the home government chooses $d_H = 1$, the optimal strategy for the foreign government is $d_F = 2$.

(ii) When $\sigma^2 \geq \overline{\sigma}^2$, $d_H = 2$ is the dominant strategy for the home government. Given that the home government chooses $d_H = 2$, the optimal strategy for the foreign government is $d_F = 1$.

(iii) When $\underline{\sigma}^2 < \sigma^2 < \overline{\sigma}^2$, we know that the optimal strategy for the home government is $d_H = d_F$, while that for the foreign government is $d_F \neq d_H$. As a result, there is no pure strategy SPNE. Let p_H and p_F be the probabilities that $d_H = 1$ and $d_F = 1$, respectively. Then, for the foreign government to randomize its timing decision, it must be true that, given p_H, the foreign government is indifferent between choosing $d_F = 1$ and choosing $d_F = 2$. That is,

$$p_H EW_F^{(1,1)} + (1 - p_H) EW_F^{(2,1)} = p_H EW_F^{(1,2)} + (1 - p_H) EW_F^{(2,2)}.$$

Solving the above equation yields

$$p_H = \frac{405(a + 3c_H - 4c_F)^2}{2133(a + 3c_H - 4c_F)^2 + 2450\sigma^2},$$

which is in (0, 1) as $\sigma^2 \in (\underline{\sigma}^2, \overline{\sigma}^2)$. Similarly, for the home government to randomize its timing decision, it must be true that, given p_F, the home government is indifferent between choosing $d_H = 1$ and choosing $d_H = 2$. That is,

$$p_F EW_H^{(1,1)} + (1 - p_F) EW_H^{(1,2)} = p_F EW_H^{(2,1)} + (1 - p_F) EW_H^{(2,2)}.$$

Solving the above equation yields

$$p_F = \frac{19125\sigma^2 - 720(a + 3c_H - 4c_F)^2}{3411(a + 3c_H - 4c_F)^2 - 475\sigma^2},$$

which is in (0, 1) as $\sigma^2 \in (\underline{\sigma}^2, \overline{\sigma}^2)$. Thus, (p_H, p_F) is the unique mixed-strategy SPNE timing in this case. □

To understand the intuition underlying Proposition 3, first consider the case where the demand uncertainty is low. In this case, the value of new information to the home government (i.e., the option value of waiting) is small and thus flexibility is not an important factor for the home government to consider. It can be easily shown that the home country's welfare reaches the maximum in subgame (1, 2).[3] Thus, the dominant strategy of the home government is to move first and to commit to the most advantageous position. Since it is always optimal for the foreign government not to match the home government's timing decision, the foreign government chooses to move second. The unique SPNE is the dominant-strategy equilibrium. Collie (1994) derives the same equilibrium in the absence of the demand uncertainty (i.e., $\sigma^2 = 0$).

When the demand uncertainty is high, new information becomes a valuable asset to the home government (i.e., the option value of waiting is large). The advantage of commitment to the home government no longer outweighs the disadvantage of inflexibility. The dominant strategy of the home government is $d_H = 2$.[4] Given this, it becomes optimal for the foreign government to move first. Thus, the unique SPNE is the dominant-strategy equilibrium.

When the demand uncertainty is moderate, the advantage of commitment to the home country may or may not outweigh the disadvantage of inflexibility, depending on the timing decision of the foreign government.[5] As a result, the home government randomizes its timing decision. Given this, the foreign government has to randomize its timing decision as well since it is never optimal for the foreign government to move synchronously with the home government.

An immediate implication of Proposition 3 is that countervailing duties are used in equilibrium by the home government when the random demand shock is sufficiently volatile (i.e., $\sigma^2 > \underline{\sigma}^2$). As such, uncertainty in the economic environment might be a key factor that rationalizes the prevailing use of countervailing duties in practice.

4. Concluding Remarks

In this paper, we have shown that the endogenous timing in a strategic trade policy game under demand uncertainty is influenced by a trade-off between commitment and flexibility. When the demand uncertainty is low, the home government will commit to its import tariff prior to the resolution of the uncertain demand condition, while the foreign government chooses its export subsidy after observing the realization of the random demand shock and the home import tariff. Thus, countervailing duties are not used in this case as concluded by Collie (1994). However, when the degree of the demand uncertainty reaches a threshold level, the equilibrium sequence of moves will be reversed. That is, the foreign government sets its export subsidy before the resolution of the demand uncertainty, while the home government sets its import tariff after observing the realization of the random demand shock and the foreign export subsidy. Thus, in contrast to Collie (1994), the prevailing use of countervailing duties is rationalized in an imperfectly competitive trading world with turbulent economic environment.

Appendix

Given that $P(Q) = a - bQ$, the Cournot-Nash equilibrium outputs that solve (1) and (2) are given by

$$q_H = \frac{1}{3b}(a + \theta - 2c_H + c_F - s + t),$$

$$q_F = \frac{1}{3b}(a + \theta + c_H - 2c_F + 2s - 2t).$$

Substituting these outputs into (5) and (6), home welfare and foreign welfare are, respectively, given by

$$\begin{aligned} W_H &= \frac{1}{18b}(2a + 2\theta - c_H - c_F + s - t)^2 + \frac{1}{9b}(a + \theta - 2c_H + c_F - s + t)^2 \\ &\quad + \frac{t}{3b}(a + \theta + c_H - 2c_F + 2s - 2t), \qquad \text{(A1)} \\ W_F &= \frac{1}{9b}(a + \theta + c_H - 2c_F - s - 2t)(a + \theta + c_H - 2c_F + 2s - 2t). \qquad \text{(A2)} \end{aligned}$$

Subgame (1, 1). In this subgame, both governments have chosen to announce their trade policies in stage one. Since the demand uncertainty has not yet been resolved, each government sets its trade policy so as to maximize its own expected social welfare. Taking expectations of (A1) and (A2) with respect to $\tilde{\theta}$ yields

$$\begin{aligned} EW_H &= \frac{1}{18b}(2a - c_H - c_F + s - t)^2 + \frac{1}{9b}(a - 2c_H + c_F - s + t)^2 \\ &\quad + \frac{t}{3b}(a + c_H - 2c_F + 2s - 2t) + \frac{\sigma^2}{3b}, \qquad \text{(A3)} \\ EW_F &= \frac{1}{9b}(a + c_H - 2c_F - s - 2t)(a + c_H - 2c_F + 2s - 2t) + \frac{\sigma^2}{9b}. \qquad \text{(A4)} \end{aligned}$$

Taking the first-order conditions of (A3) and (A4) and solving for the Nash equilibrium trade policies yields

$$t^{(1,1)} = \frac{1}{14}(5a + c_H - 6c_F),$$

$$s^{(1,1)} = \frac{1}{14}(a + 3c_H - 4c_F).$$

Substituting the above into (A3) and (A4) yields the equilibrium expected social welfare of the home and foreign countries in subgame (1, 1):

$$EW_H^{(1,1)} = \frac{39}{98b}(a + 3c_H - 4c_F)^2 - \frac{3}{b}(a + c_H - 2c_F)(c_H - c_F) + \frac{\sigma^2}{3b},$$

$$EW_F^{(1,1)} = \frac{1}{98b}(a + 3c_H - 4c_F)^2 + \frac{\sigma^2}{9b}.$$

Subgame (2, 2). In this subgame, both governments have chosen to announce their trade policies in stage two. Since both governments have observed the realized random demand shock in stage two, they set their trade policies so as to maximize their own social welfare (A1) and (A2) given that $\tilde{\theta} = \theta$. Taking the first-order conditions of (A1) and (A2) and solving for the Nash equilibrium trade policies yields

$$t^{(2,2)}(\theta) = \frac{1}{14}(5a + 5\theta + c_H - 6c_F),$$

$$s^{(2,2)}(\theta) = \frac{1}{14}(a + \theta + 3c_H - 4c_F).$$

Substituting the above into (A1) and (A2) and taking expectations with respect to $\tilde{\theta}$ yields the equilibrium expected social welfare of the home and foreign countries in subgame (2, 2):

$$EW_H^{(2,2)} = \frac{39}{98b}(a + 3c_H - 4c_F)^2 - \frac{3}{b}(a + c_H - 2c_F)(c_H - c_F) + \frac{39\sigma^2}{98b},$$

$$EW_F^{(2,2)} = \frac{1}{98b}(a + 3c_H - 4c_F)^2 + \frac{\sigma^2}{98b}.$$

Subgame (1, 2). In this subgame, the home government has committed to its import tariff set in stage one but the foreign government has delayed its trade policy choice until stage two. The SPNE is obtained by first solving stage two for the optimal foreign export subsidy as a function of the home import tariff set in stage one, and then using this solution to obtain the optimal home import tariff.

In stage two, after observing the realized random demand shock, $\tilde{\theta} = \theta$, the foreign government sets its export subsidy so as to maximize its social welfare (A2) given the home import tariff, t. Solving the first-order condition of (A2) yields

$$s = \frac{1}{4}(a + \theta + c_H - 2c_F - 2t). \tag{A5}$$

In stage one, the home government sets its import tariff so as to maximize its expected social welfare, anticipating that the optimal foreign export subsidy is given by (A5). Substituting (A5) into (A1) and taking expectation with respect to $\tilde{\theta}$ yields

$$\begin{aligned} EW_H &= \frac{1}{32b}(3a - c_H - 2c_F - 2t)^2 + \frac{1}{16b}(a - 3c_H + 2c_F + 2t)^2 \\ &\quad + \frac{t}{2b}(a + c_H - 2c_F - 2t) + \frac{11\sigma^2}{32b}. \end{aligned} \tag{A6}$$

Taking the first-order condition of (A6) and solving for the optimal home import tariff and foreign export subsidy yields

$$t^{(1,2)} = \frac{1}{10}(3a - c_H - 2c_F),$$

$$s^{(1,2)}(\theta) = \frac{1}{10}(a + 3c_H - 4c_F) + \frac{\theta}{4}.$$

Substituting the above into (A1) and (A2) and taking expectation with respect to $\tilde{\theta}$ yields the equilibrium expected social welfare of the home and foreign countries in subgame (1, 2):

$$EW_H^{(1,2)} = \frac{2}{5b}(a + 3c_H - 4c_F)^2 - \frac{3}{b}(a + c_H - 2c_F)(c_H - c_F) + \frac{11\sigma^2}{32b},$$

$$EW_F^{(1,2)} = \frac{1}{50b}(a + 3c_H - 4c_F)^2 + \frac{\sigma^2}{8b}.$$

Subgame (2, 1). In this subgame, the foreign government has committed to its export subsidy set in stage one but the home government has delayed its trade policy choice until stage two. The SPNE is obtained by first solving stage two for the optimal home import tariff as a function of the foreign export subsidy set in stage one, and then using this solution to obtain the optimal foreign export subsidy.

In stage two, after observing the realized random demand shock, $\tilde{\theta} = \theta$, the home government sets its import tariff so as to maximize its social welfare (A1) given the foreign export subsidy, s. Solving the first-order condition of (A1) yields

$$t = \frac{1}{3}(a + \theta - c_F + s). \tag{A7}$$

In stage one, the foreign government sets its export subsidy so as to maximize its expected social welfare, anticipating that the optimal home import tariff is given by (A7). Substituting (A7) into (A2) and taking expectation with respect to $\tilde{\theta}$ yields

$$EW_F = \frac{1}{81b}(a + 3c_H - 4c_F - 5s)(a + 3c_H - 4c_F + 4s) + \frac{\sigma^2}{81b}. \tag{A8}$$

Taking the first-order condition of (A8) and solving for the optimal home import tariff and foreign export subsidy yields

$$t^{(2,1)}(\theta) = \frac{1}{40}(13a - c_H - 12c_F) + \frac{\theta}{3},$$

$$s^{(2,1)} = -\frac{1}{40}(a + 3c_H - 4c_F).$$

Substituting the above into (A1) and (A2) and taking expectation with respect to $\tilde{\theta}$ yields the equilibrium expected social welfare of the home and foreign countries in subgame (2, 1):

$$EW_H^{(2,1)} = \frac{309}{800b}(a + 3c_H - 4c_F)^2 - \frac{3}{b}(a + c_H - 2c_F)(c_H - c_F) + \frac{7\sigma^2}{18b},$$

$$EW_F^{(2,1)} = \frac{1}{80b}(a + 3c_H - 4c_F)^2 + \frac{\sigma^2}{81b}.$$

Acknowledgements

We would like to thank an anonymous referee for helpful comments. The usual disclaimer applies.

Notes

1. Other examples include Brander and Spencer (1985), Dixit (1988), and Cooper and Riezman (1989), to name just a few.

2. Given the assumptions on P, the second-order conditions as well as the stability condition are satisfied.

3. If $\sigma^2 \leq \underline{\sigma}^2$, then $EW_H^{(1,2)} > EW_H^{(2,2)} > EW_H^{(1,1)} > EW_H^{(2,1)}$.

4. If $\sigma^2 \geq \overline{\sigma}^2$, then $EW_H^{(2,2)} > EW_H^{(2,1)} > EW_H^{(1,2)} > EW_H^{(1,1)}$.

5. If $\underline{\sigma}^2 < \sigma^2 < \overline{\sigma}^2$, then $EW_H^{(2,2)} > EW_H^{(1,2)} > EW_H^{(1,1)} > EW_H^{(2,1)}$.

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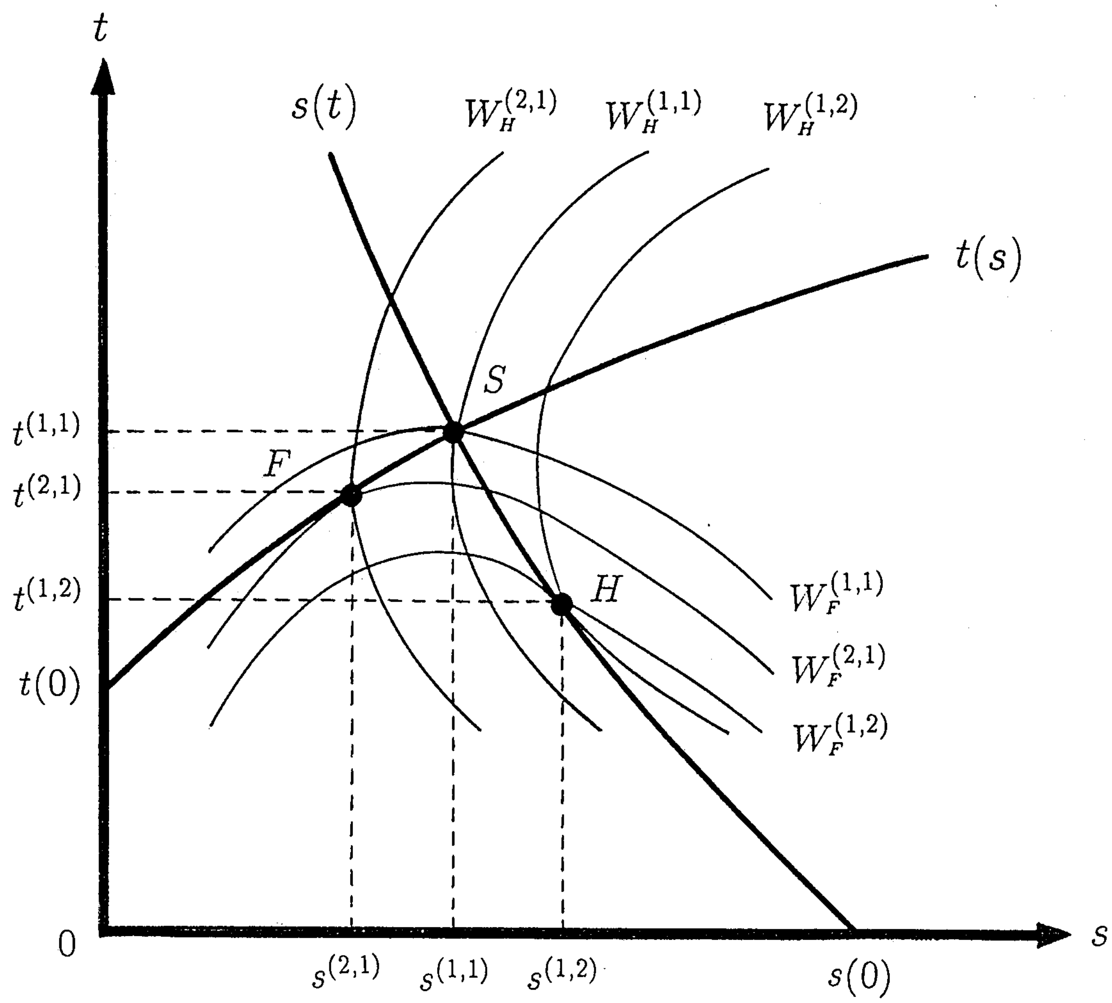

Fig. 1. Nash equilibria in the four subgames.

		Foreign government	
		1	2
Home government	1	$W_H^{(1,1)}, W_F^{(1,1)}$	$W_H^{(1,2)}, W_F^{(1,2)}$
	2	$W_H^{(2,1)}, W_F^{(2,1)}$	$W_H^{(2,2)}, W_F^{(2,2)}$

Fig. 2. Payoff matrix for the strategic trade policy game of timing.