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Strategic Trade Policy and Signalling with Unobservable Costs

by

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ABSTRACT

A two-period simultaneous signalling model is developed in which first period outputs not only signal a firm's costs to its competitor, but also signal its costs to a home country government. It is shown that the existence of second period home country strategic trade policy increases the incentives that both home and foreign high-cost firms have to misrepresent themselves as low cost. As a result, in the unique separating sequential equilibrium of this signalling game, second period strategic trade policy induces low-cost firms to distort their first period outputs more than otherwise. The major implication of this result is that the existence of second period strategic trade policy can reduce welfare.

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1. Introduction

In an internationally oligopolistic industry, the use of export/output subsidies by a home country government to shift profits away from foreign firms to home firms has become known in the literature as strategic trade policy [Brander and Spence (1985)]. It is well known that the strategic trade policy argument is not a general argument for industry assistance, but rather an argument for assistance under specific conditions. This has led many authors to caution its use [Grossman (1986)]. In a recent paper Brainard and Martimort (1992) continue this tradition of caution by demonstrating, in the presence of incomplete information about firms' costs, that the optimal trade policy may involve an export/output tax rather than a subsidy. To obtain this result, Brainard and Martimort solve a mechanism design problem and assume that firms know each others costs although the home government does not. This assumption seems quite restrictive especially when one considers the substantial industrial organization literature which is based on the assumption that firms do not know each others costs [Milgrom and Roberts (1982) and Mailath (1988, 1989)]. In this literature firms produce in each of two periods and signal their costs through their first period choices. Rather than use the mechanism design approach (screening) of Brainard and Martimort, this paper marries the signalling literature with the strategic trade policy literature to ascertain the welfare effects of strategic trade policy in the presence of unobservable costs.

In section 2 a discrete two-period simultaneous signalling model of duopoly is developed. One firm is located in the home country the other in the foreign country. The model is similar to Mailath (1989) except output is the choice variable rather than price and firms are either high cost or low costs rather than being drawn from a continuum of costs. Each firm's costs are private information though at the end of the first period each firm observes the first period output of its competitor and uses this to update its prior probability assessment of the costs of its competitor. Each firm then chooses second period output. In the first period a high-cost firm has an incentive to misrepresent itself as a low-cost firm, through it first period choice, to induce its competitor to produce a low output in the second period. It is shown that the unique separating sequential equilibrium of this game involves (1) the low-cost firm signalling the fact that it is low cost by choosing a first period output which is greater than the profit maximising output of a low-cost firm, (2) the high-cost firm signalling the fact that it is high cost by choosing the first period profit maximising output of a high-cost firm, and (3) both types of firms choosing the profit maximising output in the second period given the updated probability assessments.

In section 3 strategic trade policy is discussed. To provide the strongest case for strategic trade policy it is assumed that firms choose output, that there is no entry, that there is only one home firm, that output is sold in a third market, and that only the home government implements strategic trade policy. It is also assumed that strategic trade policy is undertaken in period 2 after the government observes the first period output signals of the home and foreign firms. Therefore, first period output not only signals a firm's costs to its competitor, but also to the home country government. It is shown that a low-cost home firm receives a bigger per-unit subsidy than a high-cost home firm and that the home firm receives a smaller per-unit subsidy if the foreign firm is low cost.

The implications of second period home government strategic trade policy for first period output choices are explored in section 4. It is shown that the existence of second period strategic trade policy increases the incentives that both home and foreign high-cost firms have to misrepresent themselves as low cost. As a result, in the unique separating sequential equilibrium of the signalling game, second period strategic trade policy induces low-cost home and foreign firms to distort their first period outputs more than otherwise.

The sequence of firm and government actions which is assumed has the firms moving first through their choice of first period outputs, the governments moving second through their choice of second period subsidies, and finally, given these subsidies, the firms moving again through their choice of second period outputs. Modelling firms as the first movers

is not new to the trade policy literature. Carmichael (1987) and Gruenspecht (1988) do precisely this, though under conditions of symmetric information, and justify the sequence of moves on the observed and stated practices of the U.S. Export-Import Bank.

The welfare implications of second period home government strategic trade policy are discussed in section 5. There are three effects to consider. The first is the usual profit shifting effect in period 2 which increases welfare. The second is the output distortion effect in period 1 which decreases welfare and the third is the profit shifting effect in period 1 which can increase or decrease welfare. Due to the complexity of the model numerical methods are used to show that there are parameter values which result in the existence of period 2 strategic trade policy decreasing welfare. Some concluding remarks are made in section 6.

2. Simultaneous Signalling in Duopoly

It is assumed that two firms, one located in the home country the other in the foreign country, sell homogeneous output in a third country or market.[1] Foreign variables are denoted by an asterisk. The inverse demand function in the third country is assumed to be linear and given by $p = a - b \cdot (q + q^*)$, where p is the per-unit price when q units of home output and q^* units of foreign output are sold and a and b are strictly positive.

The firms simultaneously choose output in each of two periods, 1 and 2. In the first period each firm's costs are private information and unknown to the other firm, however, it is known that the other firm has constant marginal costs which can be either high or low. It is assumed that the foreign firm attaches probabilities ρ and $(1 - \rho)$ to the home firm having marginal costs c^L and c^H, respectively, where $c^L < c^H$. The home firm attaches probabilities ρ^* and $(1 - \rho^*)$ to the foreign firm having marginal costs c^{L*} and c^{H*}, respectively, where $c^{L*} < c^{H*}$. At the end of the first period, each firm observes the first period output of its competitor and uses this to update its prior on the costs of its competitor. Let $\rho(q_1)$ and

[1] This is the traditional set up in the strategic trade policy literature [Brander and Spencer (1985)].

$\rho^*(q_1^*)$ be these updated priors, where q_1 and q_1^* are the first period outputs of the home and foreign firms respectively. Each firm then chooses second period output. A high-cost firm has an incentive to misrepresent itself as a low-cost firm to induce its competitor to produce a low output in the second period. In equilibrium each firm understands this incentive and allows for it when inferring first period costs from first period outputs.

This two-period game is an example of a simultaneous signalling game [Mailath (1988, 1989)]. The equilibrium concept used is sequential equilibrium [Kreps and Wilson (1982)] which in this setting is a list of period 1 and 2 outputs for each type of each firm, $(q_1^i(c^i), q_2^i(c^i, q_1, q_1^*))$ and $(q_1^{j*}(c^{j*}), q_2^{j*}(c^{j*}, q_1, q_1^*))$, $i = H, L$; $j = H, L$ and a system of beliefs, $(\rho, \rho(q_1))$ and $(\rho^*, \rho^*(q_1^*))$, that are consistent with each other and satisfy sequential rationality at every information set. That is, $(q_1^i(\cdot), q_2^i(\cdot))$ and $(q_1^{j*}(\cdot), q_2^{j*}(\cdot))$ form a Bayesian-Nash equilibrium and firms choose output optimally in the second period given $\rho(q_1)$ and $\rho^*(q_1^*)$.[2]

This paper is solely concerned with the separating sequential equilibria of the simultaneous signalling game and can be justified, as in Mailath (1989), on the grounds that these equilibria maximise the amount of information transmitted and are the equilibria most often studied.[3] In a separating sequential equilibrium private information about costs is fully revealed by first period outputs. Therefore, in the second period firms essentially play a game of complete information. This simplifies the solution of the game which begins by solving for the period 2 strategies first.

2.1. Period 2

In a separating sequential equilibrium the second period game is a game of complete information. Each firm knows the other firm's costs. The equilibrium concept used is Nash

[2] In a Bayesian-Nash equilibrium $(q_1^i(\cdot), q_2^i(\cdot))$ is a best response to $(q_1^{j*}(\cdot), q_2^{j*}(\cdot))$ and vice versa.

[3] In one-sided signalling games pooling equilibria can often be refined away using equilibrium domination when forming out-of-equilibrium beliefs [Cho and Kreps 1987, Wright 1993].

equilibrium in outputs. The home firm's problem is

$$\max_{q_2^i} \{\Pi_2^i \equiv (a - b\cdot(q_2^i + q_2^{j*}) - c^i)\cdot q_2^i\}, \quad i = H, L; \quad j = H, L. \tag{1}$$

The first order condition of this problem can be solved for $q_2^i(q_2^{j*}, c^i)$. This is commonly referred to as the home firm's reaction function; however, following Dixit (1986) it will be referred to as the home firm's equilibrium locus. The foreign firm faces a similar problem and its equilibrium locus is given by $q_2^{j*}(q_2^i, c^{j*})$. The second order conditions for a maximum and the stability conditions are satisfied.

The two equilibrium loci are solved simultaneously for the Nash equilibrium in outputs. Assuming an interior solution, these outputs are given by

$$\hat{q}_2^i = \frac{a - 2c^i + c^{j*}}{3b} \tag{2}$$

and

$$\hat{q}_2^{j*} = \frac{a - 2c^{j*} + c^i}{3b}, \tag{3}$$

where the $\hat{}$ signifies the Nash equilibrium solution. Substitution of the Nash equilibrium solutions into the objective function of each firm yields maximised profit denoted by

$$\hat{\Pi}_2(c^i, c^{j*}) = \frac{(a - 2c^i + c^{j*})^2}{9b} \tag{4}$$

and $\hat{\Pi}_2^*(c^i, c^{j*})$. These represent the maximised profit of the home and foreign firm when the marginal cost of each firm is given by c^i and c^{j*} respectively.

For later reference it is convenient to define $\hat{\Pi}_2(c^i|c^k, c^{j*})$, $i \neq k = H, L$ as the maximised value of home firm profit where, the foreign firm's costs are c^{j*} and the home firm's costs are c^i, but the home firm signals via first period output that its costs are c^k.

$$\hat{\Pi}_2(c^i|c^k, c^{j*}) = \frac{(a - 1.5c^i + c^{j*} - .5c^k)^2}{9b} \tag{5}$$

is obtained by substituting $\hat{q}_2^{j*}$, evaluated at (c^k, c^{j*}), and $q_2^i(\hat{q}_2^{j*}, c^i)$ into the objective function of the home firm. $\hat{\Pi}_2^*(c^i, c^{j*}|c^{k*})$, $j^* \neq k^* = H, L$ is defined in a similar fashion for the foreign firm.

2.2. Period 1

In period 1 the costs of each firm are private information and unknown to the other firm. In a separating sequential equilibrium each firm signals each of its possible costs with a different first period output. For the home firm, the low–cost signal q_1^L must be associated with the foreign firm's posterior (up dated) belief $\rho(q_1^L) = 1$; the high–cost signal q_1^H must be associated with the foreign firm's posterior belief $\rho(q_1^H) = 0$; and it suffices for any other signal q_1^i to be associated with posterior belief $\rho(q_1^i) = 0,\ i \neq H, L$. Similar posterior beliefs are attached to the signals of the foreign firm.

Let the home firm's first period expectation of second period profits, if the home firm is high cost, be given by $E\hat{\Pi}_2^H = \rho^* \cdot \hat{\Pi}_2(c^H, c^{L*}) + (1-\rho^*) \cdot \hat{\Pi}_2(c^H, c^{H*})$ and let the home firm's first period expectation of second period profits, if the home firm is high cost, but has signalled that it is low cost, be given by $E\hat{\Pi}_2^{H|L} = \rho^* \cdot \hat{\Pi}_2(c^H|c^L, c^{L*}) + (1-\rho^*) \cdot \hat{\Pi}_2(c^H|c^L, c^{H*})$. Define $E\hat{\Pi}_2^{H*}, E\hat{\Pi}_2^{H*|L*}, E\hat{\Pi}_2^L, E\hat{\Pi}_2^{L|H}, E\hat{\Pi}_2^{L*}$, and $E\hat{\Pi}_2^{L*|H*}$ similarly.

Separating sequential equilibria must satisfy the following self–selection (incentive compatibilty) constraints

$$\Pi_1^H(q_1^H, Eq_1^*) + E\hat{\Pi}_2^H \geq \Pi_1^H(q_1^L, Eq_1^*) + E\hat{\Pi}_2^{H|L}, \tag{6}$$

$$\Pi_1^{H*}(q_1^{H*}, Eq_1) + E\hat{\Pi}_2^{H*} \geq \Pi_1^{H*}(q_1^{L*}, Eq_1) + E\hat{\Pi}_2^{H*|L*}, \tag{7}$$

$$\Pi_1^L(q_1^L, Eq_1^*) + E\hat{\Pi}_2^L \geq \Pi_1^L(q_1^H, Eq_1^*) + E\hat{\Pi}_2^{L|H}, \tag{8}$$

and

$$\Pi_1^{L*}(q_1^{L*}, Eq_1) + E\hat{\Pi}_2^{L*} \geq \Pi_1^{L*}(q_1^{L*}, Eq_1) + E\hat{\Pi}_2^{L*|H*}, \tag{9}$$

where $\Pi_1^H(q_1^H, Eq_1^*)$ is the profit of the home firm in period 1 if its costs are c^H, its output is q_1^H, and the expected output of the foreign firm is $Eq_1^* = \rho^* \cdot q_1^{L*} + (1-\rho^*) \cdot q_1^{H*}$; $\Pi_1^H(q_1^L, Eq_1^*)$ is the profit of the home firm in period 1 if its costs are c^H, its output is q_1^L, and Eq_1^* is defined as above; and $\Pi_1^{H*}(\cdot), \Pi_1^L(\cdot)$, and $\Pi_1^{L*}(\cdot)$ are defined similarly.

Self–selection constraint (6) states that the high–cost home firm would prefer to produce q_1^H in period 1 and be perceived as high cost in period 2 rather than be perceived as low cost in period 2 and be forced to produce q_1^L in period 1. Constraint (7) is a similar condition for the foreign firm. Self selection constraint (8) states that the low–cost home firm would prefer to produce q_1^L in period 1 and be perceived as low cost in period 2 rather than be perceived as high cost in period 2 and be forced to produce q_1^H in period 1. Constraint (9) is a similar condition for the foreign firm. In a separating sequential equilibrium, given that $\rho(q_1) = 0\ \forall\ q_1 \neq q_1^L$, the high–cost home firm chooses q_1^H to maximise $\Pi_1^H(q_1^H, Eq_1^*)$. Let the solution to this problem be given by $\hat{q}_1^H(Eq_1^*)$. An identical argument applies to the high–cost foreign firm. Let the solution to its maximisation problem be given by $\hat{q}_1^{H*}(Eq_1)$.

To obtain the period 1 separating sequential equilibrium output of the low–cost home firm constraint (6) is used. Similar arguments are then used to obtain the output of the low–cost foreign firm from constraint (7). Finally it is shown that when constraints (6) and (7) bind, constraints (8) and (9) do not. The discrete nature of this problem means that constraints (6) and (7) may not bind.[4] In the Appendix conditions are derived under which both (6) and (7) bind. For the pursoses of this paper these conditions are assumed to be satisfied.

Consider Figure 1 where $\Pi_1^H(\cdot)$ and $\Pi_1^L(\cdot)$ are drawn. Given the assumptions of linear demand and constant marginal costs, both of these function are strictly concave and have maximums at $\hat{q}_1^H$ and $\hat{q}_1^L$, respectively, where $\hat{q}_1^H < \hat{q}_1^L$. The $(\cdot)$ have been dropped for notational convenience. For a given q_1, $\Pi_1^H(\cdot) < \Pi_1^L(\cdot)$. For outputs associated with positive profits, Π_1^H has an axis of symmetry at $\hat{q}_1^H$ and Π_1^L has an axis of symmetry at $\hat{q}_1^L$. In period 1 $E\hat{\Pi}_2^H$ and $E\hat{\Pi}_2^{H|L}$ are constants. $E\hat{\Pi}_2^H < E\hat{\Pi}_2^{H|L}$ because second period equilibrium loci slope downwards and the foreign firm produces less output if it believes the home firm is low cost rather than high cost. $\Pi_1^H(q_1^H, Eq_1^*) + E\hat{\Pi}_2^H$ and $\Pi_1^H(q_1^L, Eq_1^*) + E\hat{\Pi}_2^{H|L}$ are also

[4] In Mailath (1988, 1989) and Riley (1987) in which there are a contiuum of types, envelope theorem arguments establish that the self-selection constraints bind. These arguments can not be used in the discrete framework of this paper.

shown in Figure 1.

A multiplicitly of separating sequential equilibria exist for the home firm as there are many outputs q_1^L that satisfy (6). In Figure 1 these are represented by any q_1^L such that $q_1^L \geq \tilde{q}_1^L$ or $q_1^L \leq q_1^{L0}$. However, only one separating sequential equilibrium survives once dominated strategies are eliminated when forming out-of-equilibrium beliefs. Once again refer to Figure 1 and in particular output q_1^{L1}. This output forms part of a separating sequential equilibrium only because the foreign firm's posterior belief after observing an out-of-equilibrium output like q_1^{L2} is that $\rho(q_1^{L2}) = 0$. Nevertheless, the output q_1^{L2} is dominated for the high-cost firm by output $\hat{q}_1^H$. Therefore, if the foreign firm believes that the home firm would not choose a dominated output, the only posterior belief possible on observing output q_1^{L2} is that $\bar{\rho}(q_1^{L2}) = 1$. This overturns the equilibrium involving q_1^{L1} because the posterior belief on which it is based is found to be implausible. In particular, the low-cost firm would deviate from the equilibrium involving q_1^{L1} in favour of an equilibrium involving q_1^{L2} because q_1^{L2} yields more profit (q_1^{L2} is closer to the complete information profit maximising solution than q_1^{L1}.) A similar argument can be applied to any $q_1^L > \tilde{q}_1^L$ and any $q_1^L \leq q_1^{L0}$, therefore, the only separating solution that survives once dominated strategies are eliminated when forming out-of-equilibrium beliefs involves the high-cost home firm signalling its costs with $\hat{q}_1^H(Eq_1^*)$ and the low-cost home firm signalling its costs with $\tilde{q}_1^L(Eq_1^*)$.[5]

Using identical analysis on constraint (7) yields a unique solution in which the high-cost foreign firm signals its costs with $\hat{q}_1^{H*}(Eq_1)$ and the low-cost foreign firm signals its costs with $\tilde{q}_1^{L*}(Eq_1)$.[6] To date only constraints (6) and (7) have been considered.

Lemma 1: *If constraints (6) and (7) bind, then constraints (8) and (9) do not.*

5 $\tilde{q}_1^L$ yields more profit to the low-cost firm than q_1^{L0} because $\hat{q}_1^H < \hat{q}_1^L$ and $\Pi_1^H(\cdot)$ and $\Pi_1^L(\cdot)$ have axes of symmetry at $\hat{q}_1^H$ and $\hat{q}_1^L$ respectively.

6 These unique separating sequential equilibrium for the home and foreign firms have similarities with the one sided unique separating sequential equilibrium obtained by Cho and Kreps (1987) for the Spence (1973) signalling model.

Proof: First consider constraints (6) and (8). Given the functional forms of the demand and cost functions, in the Appendix it is shown that $E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H < E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H}$. It is also shown that $\frac{\partial \Pi_1^H}{\partial q_1^H} < \frac{\partial \Pi_1^L}{\partial q_1^L}$, where $q_1^H = q_1^L$. Now $\Pi_1^L(\hat{q}_1^L, \cdot) - \Pi_1^L(\tilde{q}_1^L, \cdot) < \Pi_1^H(\hat{q}_1^H, \cdot) - \Pi_1^H(\tilde{q}_1^L, \cdot)$ because $\tilde{q}_1^L - \hat{q}_1^L < \tilde{q}_1^L - \hat{q}_1^H$ and $\frac{\partial \Pi_1^H}{\partial q_1^H} < \frac{\partial \Pi_1^L}{\partial q_1^L}$, where $q_1^H = q_1^L$. If constraint (6) binds, then $\Pi_1^H(\hat{q}_1^H, \cdot) - \Pi_1^H(\tilde{q}_1^L, \cdot) = E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H$. As $E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H < E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H}$ and $\Pi_1^L(\hat{q}_1^H, \cdot) < \Pi_1^L(\hat{q}_1^L, \cdot)$ it must be the case that $\Pi_1^L(\hat{q}_1^H, \cdot) - \Pi_1^L(\tilde{q}_1^L, \cdot) < E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H}$. This latter inequality can be rearranged to yield

$$\Pi_1^L(\tilde{q}_1^L, \cdot) + E\hat{\Pi}_2^L > \Pi_1^L(\hat{q}_1^H, \cdot) + E\hat{\Pi}_2^{L|H} \tag{10}$$

which is constraint (8). A similar argument can be applied to constraints (7) and (9). **(Q.E.D.)**

Lemma 1 establishes that if constraints (6) and (7) bind, then constraints (8) and (9) do not and can be ignored when solving for the separating sequential equilibrium. For the remainder of this paper it is assumed that (6) and (7) bind.

To be part of a separating sequential equilibrium $(\hat{q}_1^H(Eq_1^*), \hat{q}_2^H), (\tilde{q}_1^L(Eq_1^*), \hat{q}_2^L)$, $(\hat{q}_1^{H*}(Eq_1), \hat{q}_2^{H*})$ and $(\tilde{q}_1^{L*}(Eq_1), \hat{q}_2^{L*})$ must form a Bayesian-Nash equilibrium. The above discussion is summarised in the following proposition.

Proposition 1: *The unique separating sequential equilibrium of the simultaneous move signalling game involves the high-cost home and foreign firms signalling their costs in period 1 with $\hat{q}_1^H(Eq_1^*)$ and $\hat{q}_1^{H*}(Eq_1)$, respectively, while the low-cost home and foreign firms signal their costs in period 1 with $\tilde{q}_1^L(Eq_1^*)$ and $\tilde{q}_1^{L*}(Eq_1)$, respectively, where $\tilde{q}_1^L(Eq_1^*) > \hat{q}_1^L(Eq_1^*)$, $\tilde{q}_1^{L*}(Eq_1) > \hat{q}_1^{L*}(Eq_1)$, $Eq_1^* = (1-\rho^*)\cdot\hat{q}_1^{H*}(\cdot) + \rho^*\cdot\tilde{q}_1^{L*}(\cdot)$, and $Eq_1 = (1-\rho)\cdot\hat{q}_1^H(\cdot) + \rho\cdot\tilde{q}_1^L(\cdot)$. In period 2 outputs are chosen optimally, given the period 1 signals, and in equilibrium are denoted by $\hat{q}_2^H, \hat{q}_2^L, \hat{q}_2^{H*}$, and $\hat{q}_2^{L*}$.*

The intuition behind the period 1 outputs of Proposition 1 is clear. The high-cost home and foreign firms are able to obtain complete information profits, given the equilibrium expected outputs of their competitor, because $\hat{q}_1^H$ and $\hat{q}_1^{H*}$ would only be chosen by high-cost firms. On the other hand, the low-cost home and foreign firms must distort their outputs away from the complete information profit maximising outputs to convince their competitor that it is indeed low cost. The minimum distortion necessary to achieve this involves outputs $\bar{q}_1^L$ and $\bar{q}_1^{L*}$. The information asymmetry imposes a cost on the low-cost home and foreign firms.

3. Strategic Trade Policy

It is assumed that the home country government can use an output/export subsidy in the second period to shift profits from the foreign firm to the home firm. The effects of this subsidy are now analysed.

In a separating sequential equilibrium the second period game is a game of complete information. This game differs from the game of section 2.1 because the home country government places a subsidy on home output before the output game is played. The home firm's problem is

$$\max_{q_2^i} \{\Pi_2^i \equiv (a - b \cdot (q_2^i + q_2^{j*}) - c^i + s) \cdot q_2^i\}, \quad i = H, L; \quad j = H, L, \tag{11}$$

where s is the per-unit output subsidy. The foreign firm faces a similar problem except its government does not place a subsidy on foreign output.

As in section 2.1, the first order conditions of the home and foreign firms' problems can be solved for the equilibrium loci, $q_2^i(q_2^{j*}, c^i, s)$ and $q_2^{j*}(q_2^i, c^{j*})$, and for the Nash equilibrium outputs,

$$q_2^i = \frac{a - 2c^i + c^{j*} + 2s}{3b} \tag{12}$$

and

$$q_2^{j*} = \frac{a - 2c^{j*} + c^i - s}{3b}. \tag{13}$$

Substitution of the Nash equilibrium outputs into each firm's objective function gives $\Pi_2(c^i, c^{j*}, s)$ and $\Pi_2^*(c^i, c^{j*}, s)$.

The home country government maximises home firm profit minus the subsidy, W_2^i, by choice of the per-unit subsidy. Its problem is

$$\max_s \{W_2^i \equiv \Pi_2^i(c^i, c^{j*}, s) - s \cdot q_2^i(c^i, c^{j*}, s)\}. \tag{14}$$

Solving the first order condition of this problem yields the optimal subsidy

$$\bar{s} = \frac{a - 2c^i + c^{j*}}{4}. \tag{15}$$

This optimal subsidy shifts the equilibrium locus of the home firm in such a way that the new Nash equilibrium outputs of the home and foreign firms coincide with what would, in the absence of a subsidy, be the Stackelberg leader-follower equilibrium outputs with the home firm as leader [Brander and Spencer (1985)]. Note that the optimal subsidy, $\bar{s}$, is decreasing in c^i and increasing in c^{j*}.

Substituting $\bar{s}$ into $\Pi_2(\cdot)$ yields maximised home firm profit, given the optimal subsidy. Let this maximised profit be denoted by

$$\bar{\Pi}_2(c^i, c^{j*}) = \frac{(a - 2c^i + c^{j*})^2}{4b}. \tag{16}$$

Let foreign firm maximised profit, given the optimal subsidy, be denoted by

$$\bar{\Pi}_2^*(c^i, c^{j*}) = \frac{(a + 2c^i - 3c^{j*})^2}{16b}. \tag{17}$$

For later reference it is convenient to define $\bar{\Pi}_2(c^i|c^k, c^{j*})$, $i \neq k = H, L$ as the maximised value of home firm profit, where the foreign firm's costs are c^{j*} and the home firm's costs are c^i, but the home firm signals via first period output that its costs are c^k.

$$\bar{\Pi}_2(c^i|c^k, c^{j*}) = \frac{(a - c^i + c^{j*} - c^k)^2}{4b} \tag{18}$$

is obtained by substituting $q_2^{j*}(c^k, c^{j*}, \bar{s}(c^k, c^{j*}))$ and $q_2^i(q_2^{j*}(\cdot), c^i, \bar{s}(\cdot))$ into the objective function of the home firm. For the foreign firm,

$$\bar{\Pi}_2^*(c^i, c^{j*}|c^{k*}) = \frac{(a + 2c^i - 2c^{j*} - c^{k*})^2}{16b} \tag{19}$$

is defined in a similar fashion.

4. Simultaneous Signalling and Strategic Trade Policy

In the previous section it was shown that the existence of home country strategic trade policy in period 2 changed period 2 home firm profits from $\hat{\Pi}_2(\cdot)$ to $\bar{\Pi}_2(\cdot)$, where $\hat{\Pi}_2(\cdot) < \bar{\Pi}_2(\cdot)$. The subsidy not only had the direct effect of increasing home firm profit because the home firm received a subsidy of s for every unit produced, but also had the indirect effect of increasing home firm profit because the subsidy induced the foreign firm to produce less output. For the foreign firm the subsidy changed profits from $\hat{\Pi}_2^*(\cdot)$ to $\bar{\Pi}_2^*(\cdot)$, where $\hat{\Pi}_2^*(\cdot) > \bar{\Pi}_2^*(\cdot)$.

In the Appendix it is shown that

$$E\bar{\Pi}_2^{H|L} - E\bar{\Pi}_2^{H} > E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^{H}. \tag{20}$$

The low-cost home firm receives a greater subsidy than the high-cost home firm so the expected benefits of a high-cost home firm misrepresenting itself as a low-cost firm in period 1 are greater with the subsidy than without. The effect of this in the first period can be ascertained by referring to Figure 1. Although not drawn, $\Pi_1^H + E\bar{\Pi}_2^H$ and $\Pi_1^H + E\bar{\Pi}_2^{H|L}$ are vertically above $\Pi_1^H + E\hat{\Pi}_2^H$ and $\Pi_1^H + E\hat{\Pi}_2^{H|L}$ respectively. Furthermore, the vertical distance between $\Pi_1^H + E\bar{\Pi}_2^H$ and $\Pi_1^H + E\bar{\Pi}_2^{H|L}$ is greater than the vertical distance between $\Pi_1^H + E\hat{\Pi}_2^H$ and $\Pi_1^H + E\hat{\Pi}_2^{H|L}$. As a result, in period 1, for a given Eq_1^*, the low-cost home firm signals the fact that it is low cost with an output greater that $\bar{q}_1^L$. Let this output be denoted $\check{q}_1^L$, where $\check{q}_1^L > \bar{q}_1^L$. This inequality leads to home firm expected first period output being greater with the second period subsidy than without, that is,

$$(1-\rho)\cdot\hat{q}_1^H + \rho\cdot\check{q}_1^L > (1-\rho)\cdot\hat{q}_1^H + \rho\cdot\bar{q}_1^L \tag{21}$$

The foreign firm does not receive a second period subsidy, but can affect the size of the home firm's subsidy through its cost signal. The home firm receives a smaller subsidy if the foreign firm is low cost rather than high cost, therefore, the expected benefits of a

high-cost foreign firm misrepresenting itself as a low-cost firm in period 1 are greater with the subsidy than without. As for the home firm, this means that the foreign firm signals the fact that it is low cost with an output greater than $\bar{q}_1^{L*}$. Let this output be denoted $\check{q}_1^{L*}$, where $\check{q}_1^{L*} > \bar{q}_1^{L*}$. For a given Eq_1, foreign firm period 1 expected output is greater with the second period subsidy than without.

In a separating sequential equilibrium home and foreign firm first period outputs depend on two effects. The first is the signalling effect which causes q_1^L and q_1^{L*} to be greater with the subsidy than without. The second is the strategic effect. An increase in the expected output of one firm, *ceteris paribus*, decreases the equilibrium outputs of both its low cost and high-cost competitor because equilibrium loci slope down. Together these effects suggest that the separating sequential equilibrium outputs of the high-cost home and foreign firms are lower with the subsidy than without. However, this is not necessarily so.

The degree to which the low-cost home and foreign firms must distort their outputs from their profit maximising levels differs for each firm. Each firm faces different incentives to misrepresent their costs because (1) c^i and c^{j*} enter $\bar{s}$ with different coefficients (in absolute value) and (2) the high-cost home firm receives a direct benefit from a greater subsidy which the high-cost foreign firm does not. This latter effect strongly suggests that the low-cost home firm must distort its output much further than the low-cost foreign firm to satisfy the self-selection constraint and signal its true cost, although, in general, no such claim can be made. If the low-cost home firm distorts its period 1 output more than the foreign firm to signal its true costs, then the high-cost foreign firm may reduce its output to such an extent that the foreign firm's equilibrium expected output is lower with the subsidy than without.

Let the first period separating sequential equilibrium outputs of the high-cost and low-cost foreign firms be given by $\check{q}_1^{H*}$ and $\check{q}_1^{L*}$ respectively. If the equilibrium expected output of the foreign firm is lower with the subsidy than without, the equilibrium outputs of both the high and low-cost home firms are greater with the subsidy than without. Let the first period separating sequential equilibrium outputs of the high and low-cost home firms be given by $\dot{q}_1^H$ and $\dot{q}_1^L$ respectively. The preceding discussion is summarised in the following proposition.

Proposition 2: *The unique separating sequential equilibrium of the simultaneous move signalling game, in the presence of a second period output subsidy for the home firm, involves the high-cost home and foreign firms signalling their costs in period 1 with $\dot{q}_1^H$ and $\dot{q}_1^{H*}$, respectively, while the low-cost home and foreign firms signal their costs in period 1 with $\dot{q}_1^L$ and $\dot{q}_1^{L*}$, respectively. If the equilibrium expected output of the foreign firm is lower with the second period subsidy than without, then $\dot{q}_1^H > \hat{q}_1^H$, $\dot{q}_1^L > \tilde{q}_1^L > \hat{q}_1^L$, $\dot{q}_1^{H*} < \hat{q}_1^{H*}$, and $\dot{q}_1^{L*} < \tilde{q}_1^{L*} > \hat{q}_1^{L*}$.*

The second period subsidy to the home firm commits the low-cost home firm to a greater output in period 1 as a greater output is required to signal its true costs. The foreign firm notes this commitment and may produce less expected output in period 1 even though a low-cost foreign firm also requires a greater output in period 1 to signal its true costs. With the foreign firm producing less expected output in period 1, in a separating sequential equilibrium, the home firm produces more output in period 1 with the subsidy than without, regardless of its costs.

5. Welfare

In this section the welfare implications of strategic trade policy are considered. It is assumed that welfare, W, is given by the expected value of the sum of first and second period home firm expected profits net of any subsidy. Let $E\Pi^i$, $i = H, L$ denote the sum of first and second period home firm expected profits net of any subsidy, then

$$W \equiv (1-\rho)\cdot E\Pi^H + \rho \cdot E\Pi^L. \qquad (22)$$

A second period subsidy, $\bar{s}$, has three effects on home country welfare. Firstly, there is the profit shifting effect in period 2. This was discussed in section 3 above and increases expected welfare. Secondly, there is the output distortion effect in period 1. For the low-cost firm a second period subsidy increases the amount by which period 1 output must be distorted away from its complete information profit maximising level. This was discussed in section 4 above and decreases expected welfare. Thirdly, there is the profit shifting effect in period 1. The second period subsidy commits the low-cost home firm to produce greater output in period 1 and may induce the foreign to produce less expected output in period 1. This was discussed in section 4 above and increases expected welfare. Due to the complexity of the model numerical methods are used to ascertain the net effect of these three influences on welfare.

The base case has $a = 30$, $b = 1$, $\rho = \rho^* = .5$, $c^H = c^{H*} = 10$, and $c^L = c^{L*} = 5$. Table 1 shows the separating sequential equilibrium first period outputs for the home and foreign firms, q_1^L, q_1^H, q_1^{L*}, and q_1^{H*}; first period expected profits for the high and low-cost home firm, Π_1^H and Π_1^L; the sum of period 1 and period 2 expected profits net of any subsidy for the high and low-cost home firm, $E\Pi^H$ and $E\Pi^L$; and welfare, W; with and without the second period subsidy $\bar{s}$.

Table 1

	q_1^L	q_1^H	q_1^{L*}	q_1^{H*}	Π_1^H	Π_1^L	$E\Pi^H$	$E\Pi^L$	W
no subsidy	9.36	6.13	9.36	6.13	37.56	73.93	72.28	158.65	115.47
subsidy	13.81	6.74	8.17	4.86	45.47	64.53	84.53	159.85	122.19

Consider the period 1 output of the low-cost home firm. The second period subsidy increases this output substantially and is the sum of two effects. Firstly, the subsidy increases q_1^L because a larger output distortion is required to signal low cost. Second, q_1^L increases because the period 1 expected output of the foreign firm decreases. This latter effect explains the increase in q_1^H. As a result of the second period subsidy, both q_1^{L*} and q_1^{H*}

decrease in this separating sequential equilibrium because the strategic effect of the increase in the expected output of the home firm dominates the low–cost foreign firm's signalling effect. These effects were discussed in section 4.

The expected period 1 profit of the high–cost home firm, Π_1^H, increases as a result of the second period subsidy due to the decrease in foreign firm period 1 expected output. This is the profit shifting effect in period 1 of the period 2 subsidy. This profit shifting effect tends to increase Π_1^L as well; however, the output distortion effect swamps the profit shifting effect, so the expected period 1 profit of the low–cost home firm decreases as a result of the second period subsidy.

The second period output subsidy also shifts profit to the home firm in period 2. For the low–cost home firm this effect is so large that the sum of period 1 and period 2 expected profits net of any subsidy, $E\Pi^L$, is greater with the subsidy than without even though expected first period profit is lower with the subsidy than without. For the high–cost home firm the sum of period 1 and period 2 expected profits net of any subsidy, $E\Pi^H$, is greater with the subsidy than without because the period 1 and period 2 profit shifting effects reinforce each other.

Finally, welfare is greater with the subsidy than without because both $E\Pi^H$ and $E\Pi^L$ are greater with the subsidy than without. In this case, the existence of period 2 strategic trade policy umambiguosly increases home welfare.

Next consider table 2 for which $\rho = \rho^* = .2$ and the other parameters take the same values as those in the base case.

Table 2

$\rho = \rho^* = .2$	q_1^L	q_1^H	q_1^{L*}	q_1^{H*}	Π_1^H	Π_1^L	$E\Pi^H$	$E\Pi^L$	W
no subsidy	9.80	6.44	9.80	6.44	41.51	79.25	82.07	173.14	100.28
subsidy	14.01	6.68	9.51	5.93	44.60	60.90	90.22	166.52	105.48

Period 1 variables display a similar pattern to those of table 1. However, note that Π_1^L

is now significantly lower with the subsidy than without. The output distortion effect is much more dominant than the period 1 profit shifting effect. The period 1 profit shifting effect is now smaller because the period 1 outputs of the foreign firm are not reduced very much as little probability is attached to the signalling output of the low–cost home firm.

For the low–cost home firm adding the period 2 profit shifting effect is not sufficient to make $E\Pi^L$ greater with the subsidy than without. So although welfare in expected value terms is greater with the subsidy than without, if the firm in the home country is low cost, then the existence of period 2 strategic trade policy can actually make the home country worse off.

Next consider table 3 for which $c^H = 15$, $c^L = 13$, and the other parameters take the same values as those in the base case.

Table 3

$c^H = 15, c^L = 13$	q_1^L	q_1^H	q_1^{L*}	q_1^{H*}	Π_1^H	Π_1^L	$E\Pi^H$	$E\Pi^L$	W
no subsidy	3.64	2.31	12.26	8.51	5.32	10.83	12.27	26.21	19.24
subsidy	5.28	2.36	12.46	8.09	5.58	7.65	13.40	24.96	19.18

These variables display a similar pattern to those of tables 1 and 2 except here the existence of period 2 strategic trade policy unambiguously decreases home welfare. The welfare decreasing effect of the low–cost firm's first period output distortion more than offsets the welfare increasing effects of first and second period profit shifting.[7] The reduction in the first period expected profit of the low–cost home firm that results from signalling is greater the closer are c^H and c^L because greater output distortions are required to signal the firm's true costs. However, for a second period subsidy to reduce welfare, it appears that it is also necessary to have $c^H \gg c^L$ and $c^{H*} \gg c^{L*}$. The intuition for this latter condition is not clear, though it is necessary to generate a welfare decrease in the numerical analysis.[8]

7 Unlike tables 1 and 2, in table 3 q_1^{L*} is greater with the subsidy than without. The low–cost foreign firm's signalling effect is sufficient to dominate the strategic effect, though expected foreign output is lower with the subsidy than without.

8 Setting $c^H = 10$ and $c^L = 9$ does not generate a welfare decrease.

The practical significance of the cost structure in table 3 should be considered. This structure would arise if the foreign firm had access to a newer (lower cost) technology, but one that was more affected by stochastic shocks, than the technology used by the home firm. It is not claimed that the parameter values in table 3 are any more representative of real world cost conditions than tables 1 or 2, but merely that such cost conditions may exist. Given this possibility and the numerous other parameterizations of the model which make strategic trade policy welfare decreasing, the results of this section reinforce what other researchers have found, namely, that strategic trade policy is not a general argument for industry assistance, but rather an argument for assistance under a very specific set of conditions.

6. Conclusion

This paper has shown that second period strategic trade policy increases the incentives that both high-cost home and foreign firms have to misrepresent themselves as low cost. As a result, low-cost home and foreign firms must distort their first period outputs even further than otherwise from their profit maximising levels to signal that they are in fact low cost. The effect of this additional output distortion can be such that if the firm in the home country is low cost, then the existence of second period strategic trade policy can actually make the home country worse off. In fact, there are parameter values for which the output distortion of the low-cost home firm is such that the existence of second period strategic trade policy reduces expected welfare.[9] These results add to the substantial literature that cautions the general use of strategic trade policy, for even under those conditions which are most favourable to its use the existence of strategic trade policy can reduce welfare.

[9] In this case, if the home country government could commit to a policy of non-intervention prior to firms choosing first period outputs [Hwang and Schulman (1993)], such a policy would be optimal.

APPENDIX

1. Constraint (6) binds if

$$\Pi_1^H(\hat{q}_1^H) + E\hat{\Pi}_2^H < \Pi_1^H(\hat{q}_1^L) + E\hat{\Pi}_2^{H|L} \quad (A.1)$$

which on rearranging becomes

$$\Pi_1^H(\hat{q}_1^H) - \Pi_1^H(\hat{q}_1^L) < E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H. \quad (A.2)$$

Given the assumptions of this paper, this condition can be rewritten as

$$\frac{(c^L - c^H)^2}{4b} < \frac{(c^H - c^L)\cdot(4a - 7c^H + 4c^{H*} - c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*})}{36b} \quad (A.3)$$

which on rearranging becomes

$$4c^H - 2c^L < a + (1-\rho^*)\cdot c^{H*} + \rho^* \cdot c^{L*}. \quad (A.4)$$

A similar condition can be derived for constraint (7).

2. $E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H < E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H}$

Proof:

$$E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H = \frac{(c^H - c^L)\cdot(4a - 7c^H + 4c^{H*} - c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*})}{36b} \quad (A.5)$$

and

$$E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H} = \frac{(c^H - c^L)\cdot(4a - c^H + 4c^{H*} - 7c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*})}{36b}. \quad (A.6)$$

Now

$$(4a - 7c^H + 4c^{H*} - c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*}) < (4a - c^H + 4c^{H*} - 7c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*}) \quad (A.7)$$

because $c^L < c^H$, so $E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H < E\hat{\Pi}_2^L - E\hat{\Pi}_2^{L|H}$. **(Q.E.D.)**

3. $\frac{\partial \Pi_1^H}{\partial q_1^H} < \frac{\partial \Pi_1^L}{\partial q_1^L}$

Proof:

$$\frac{\partial \Pi_1^H}{\partial q_1^H} = a - b\cdot Eq_1^* - 2bq_1^H - c^H \quad (A.8)$$

$$\frac{\partial \Pi_1^L}{\partial q_1^L} = a - b \cdot Eq_1^* - 2bq_1^L - c^L \qquad (A.9)$$

If $q_1^H = q_1^L$, then $\frac{\partial \Pi_1^H}{\partial q_1^H} < \frac{\partial \Pi_1^L}{\partial q_1^L}$ because $c^H > c^L$. **(Q.E.D.)**

4. $E\bar{\Pi}_2^{H|L} - E\bar{\Pi}_2^H > E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H$

Proof:

$$E\bar{\Pi}_2^{H|L} - E\bar{\Pi}_2^H = \frac{(c^H - c^L) \cdot (4a - 6c^H + 4c^{H*} - 2c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*})}{8b} \qquad (A.10)$$

and

$$E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H = \frac{(c^H - c^L) \cdot (4a - 7c^H + 4c^{H*} - c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*})}{36b}. \qquad (A.11)$$

Now

$$(4a - 6c^H + 4c^{H*} - 2c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*}) > (4a - 7c^H + 4c^{H*} - c^L - 4\rho^* c^{H*} + 4\rho^* c^{L*}) \qquad (A.12)$$

because $c^L < c^H$, so $E\bar{\Pi}_2^{H|L} - E\bar{\Pi}_2^H > E\hat{\Pi}_2^{H|L} - E\hat{\Pi}_2^H$. **(Q.E.D.)**

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