Export Subsidies as Signals of Competitiveness*

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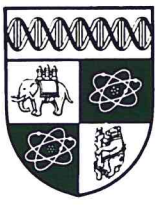

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Abstract

In a Cournot duopoly model of international competition between a domestic and foreign firm, it is shown that when the foreign firm has incomplete information about the marginal cost of the domestic firm then the domestic government can use an export subsidy to signal the competitiveness of its firm. This signalling effect strengthens the usual profit-sharing argument for an export subsidy. The optimal export subsidy in the signalling equilibrium may be twice as large as the optimal profit-shifting export subsidy under complete information

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1. Introduction

The possibility of using strategic export subsidies in oligopolistic industries to shift profits and enhance national welfare has been demonstrated by Brander and Spencer (1985). In a Cournot duopoly model, where a domestic and a foreign firm compete in a third market, they showed that a domestic export subsidy will commit the domestic firm to expand its output, and in response the foreign firm will reduce its output. This increases the profits of the domestic firm net of the export subsidy, and hence is welfare improving for the domestic country. The optimal export subsidy commits the domestic firm to produce the Stackelberg-leader output and results in the foreign firm producing the Stackelberg-follower output. The export subsidy basically gives the domestic firm a first-mover advantage. The literature on strategic trade policy is surveyed by Helpman and Krugman (1989), chapter five.[1] Previous models of strategic trade policy have all assumed that firms have complete information. This paper analyses a Cournot duopoly model where the foreign firm has incomplete information about the marginal cost of the domestic firm, then as well as the usual *profit-shifting* argument there is also a *signalling* argument for an export subsidy.[2]

When the foreign firm is uncertain about the marginal cost of the domestic firm, the lower is its expectation of domestic marginal cost then the larger will be its expectation of domestic output. In a Cournot duopoly, with downward sloping reaction functions, the foreign firm will reduce its output if it expects a larger output from the domestic firm, and this will increase the profits of the domestic firm. Thus, a lowering of the foreign

firm's expectation about domestic marginal cost increases the profits of the domestic firm. If the domestic government has a first-mover advantage and information about its firm's marginal cost, then it can use an export subsidy to influence the foreign firm's expectations about domestic marginal cost. With complete information de Meza (1986) has shown that the lower are the costs of the domestic firm then the larger is the export subsidy it receives from the domestic government. Thus, under incomplete information, a larger export subsidy may lead the foreign firm to lower its expectation of domestic marginal cost which increases the profits of the domestic firm. Hence, the domestic government has an incentive to give its firm a larger export subsidy than under complete information to signal the competitiveness of its firm. This *signalling* effect strengthens the usual *profit-shifting* effect of an export subsidy. Therefore, the export subsidy in the signalling equilibrium under incomplete information will be larger than the profit-shifting export subsidy under complete information.

The basic Cournot duopoly model where the foreign firm has incomplete information about domestic marginal cost is described in section two, and the signalling equilibrium is derived in section three. The model is extended in section four so that both firms have incomplete information about their rival's marginal costs, then both governments have an incentive to use export subsidies to signal the competitiveness of their firms. Section five shows that it is possible the domestic government will decide not to use its information about domestic marginal cost, and that there will be a pooling equilibrium where the domestic export subsidy does not depend upon the competitiveness of the domestic firm. The conclusions are presented in section six.

2. The Basic Model

The basic model is the same as in Brander and Spencer (1985) except for the introduction of incomplete information. There is a Cournot duopoly consisting of one domestic and one foreign firm exporting a homogeneous product to a third market. Assuming both firms have constant marginal cost and that markets are segmented, then the third market can be analysed independently of the domestic and foreign market. Demand in the third market is assumed to be linear. In this section it will be assumed that the incomplete information is such that the foreign firm does not know the marginal cost of the domestic firm, but that the domestic firm does know the marginal cost of the foreign firm. It is also assumed that the domestic government knows the marginal cost of the domestic firm.[3] Then, the domestic government can use an export subsidy to shift profits as in Brander and Spencer (1985), and also to signal the competitiveness of the domestic firm. The foreign government is assumed to be passive in this section.

The structure of the game is as follows: At the first stage the domestic government sets its export subsidy to maximise its national welfare. The export subsidy is observed by both the domestic firm and the foreign firm. Then, at the second stage, the domestic and foreign firm make their output decisions given the domestic export subsidy and given the beliefs of the foreign firm about domestic marginal cost. The beliefs of the foreign firm will be conditioned on the export subsidy set by the domestic government. The appropriate solution is the Perfect Bayesian Equilibrium which requires

strategies to be optimal given beliefs, and beliefs to be consistent with Bayes rule given the strategies. In particular, we will look for a signalling (separating) equilibrium where the foreign firm correctly infers the marginal cost of the domestic firm from the export subsidy set by the domestic government. At the first stage of the game the domestic government will realise that the beliefs of the foreign firm will be affected by its export subsidy and will take this signalling effect into account when it sets its export subsidy.

Domestic variables will be labelled by a subscript 1 and foreign variables by a subscript 2. The domestic firm has a constant marginal cost c_1 which is drawn from a continuous distribution with support on $[c_1^L, c_1^H]$. The domestic firm and government both know the marginal cost of the domestic firm. The foreign firm does not know c_1 but it does know the distribution of possible marginal costs. The foreign firm has a constant marginal cost c_2 which is common knowledge. The domestic government gives the domestic firm an export subsidy of e_1 per unit exported, which is common knowledge at the second stage of the game. It is assumed that the foreign government does not use an export subsidy. The domestic firm exports output q_1 and the foreign firm exports output q_2 to the third market. The price of exports is given by the linear inverse demand function:

$$P = \alpha - q_1 - q_2 \qquad (1)$$

As usual the game is solved by a process of backward induction. The first step is to solve the second stage when firms make their output decisions given the domestic export subsidy and given the beliefs of the foreign firm

about the marginal cost of the domestic firm. The profits of the domestic firm and the expected profits of the foreign firm are

$$\pi_1 = (P - c_1 + e_1)q_1$$
$$\pi_2 = E_2\left[(P - c_2)q_2 | e_1\right] \tag{2}$$

Where E_2 is the expectation operator given the beliefs of the foreign firm about the marginal cost of the domestic firm. Firms are assumed to maximise profits with quantities as the strategic variables, hence the first order conditions for a Bayesian-Nash equilibrium are

$$\partial\pi_1/\partial q_1 = \alpha - 2q_1 - q_2 - c_1 + e_1 = 0$$
$$\partial\pi_2/\partial q_2 = \alpha - E_2(q_1|e_1) - 2q_2 - c_2 = 0 \tag{3}$$

To solve for the equilibrium quantities it is first necessary to determine $E_2(q_1|e_1)$. To do this take expectations of the first order condition for the domestic firm and then use the first order condition for the foreign firm to obtain

$$E_2(q_1|e_1) = (\alpha - 2\hat{c}_1(e_1) + c_2 + 2e_1)/3 \tag{4}$$

Where $\hat{c}_1(e_1) = E_2(c_1|e_1)$ is the expectation of the foreign firm about the marginal cost of the domestic firm conditioned on the the export subsidy of the domestic government. Then, using (4) in (3) yields the equilibrium quantities

$$q_1 = (2\alpha - 3c_1 - \hat{c}_1(e_1) + 2c_2 + 4e_1)/6 = (\hat{B}_1 + 4e_1)/6$$

$$q_2 = (\alpha - 2c_2 + \hat{c}_1(e_1) - e_1)/3 \qquad (5)$$

Where $\hat{B}_1 = 2\alpha - 3c_1 - \hat{c}_1(e_1) + 2c_2$ is a measure of the competitiveness of the domestic firm given the beliefs of the foreign firm about domestic marginal cost. From (5) it can be seen that the direct effect of a domestic export subsidy is to increase the output of the domestic firm and to reduce the output of the foreign firm. The export subsidy may also have an indirect effect by influencing the beliefs of the foreign firm. A lowering of the foreign firm's expectations about domestic marginal cost will have a similar effect to an export subsidy. Using (5) in (1) yields the price-cost margin of the domestic firm

$$P - c_1 = (2\alpha - 3c_1 - \hat{c}_1(e_1) + 2c_2 - 2e_1)/6 = (\hat{B}_1 - 2e_1)/6 \qquad (6)$$

At the first stage of the game, the domestic government sets its export subsidy to maximise national welfare. Since marginal cost is constant and markets are segmented, domestic welfare is producer surplus from exports, that is profits of the domestic firm net of the export subsidy, so $W_1 = (P - c_1)q_1$. Thus, from (5) and (6) domestic welfare can be written as

$$W_1(e_1, c_1, \hat{c}_1) = (\hat{B}_1 - 2e_1)(\hat{B}_1 + 4e_1)/36 \qquad (7)$$

Before considering the signalling equilibrium in the game of incomplete information it is useful to look at the usual profit shifting argument for

an export subsidy under complete information as in Brander and Spencer (1985). An export subsidy commits the domestic firm to increase exports which will lead the foreign firm to reduce its exports, and hence the market share of the domestic firm will increase. The profits of the domestic firm increase by more than the amount of the export subsidy, and hence there is an increase in domestic welfare. With complete information the foreign firm knows the marginal cost of the domestic firm so $\hat{c}_1(e_1) = c_1$ and $\hat{B}_1 = B_1 \equiv (2\alpha - 4c_1 + 2c_2)$, then if the domestic government sets its export subsidy to maximise national welfare (7), the first order condition for welfare maximisation is

$$\partial W_1/\partial e_1 = (B_1 - 8e_1)/18 = 0 \qquad (8)$$

Thus, the optimum profit-shifting export subsidy with complete information is given by $e_1^* = B_1/8 > 0$, and welfare is given by substituting e_1^* into (7) to obtain $W_1^* = B_1^2/32$. As de Meza (1986) has shown the optimum domestic export subsidy is increasing in the competitiveness of the domestic firm. The explanation is that the lower are the costs of the domestic firm then the larger will be its profit margin, and hence the larger will be the welfare gain to the domestic country from an export subsidy.

3. The Signalling Equilibrium

With incomplete information the domestic government would like the foreign firm to believe that the domestic firm has low costs since then the foreign firm would reduce its exports, and thus increase the profits of the domestic firm. Hence, the domestic government has an incentive to give its

firm a larger export subsidy than under complete information so that the foreign firm will infer that the domestic firm has low costs. Therefore, the export subsidy in the signalling equilibrium under incomplete information will be larger than the profit-shifting export subsidy under complete information.

The game of incomplete information described in section two has many perfect Bayesian equilibria (pooling, partial-pooling and separating equilibrium), but this section will only consider the unique signalling (separating) equilibrium of the game. In a signalling equilibrium the domestic government's export subsidy is a one-to-one function of the marginal cost of the domestic firm, and the foreign firm correctly infers the marginal cost of the domestic firm from the export subsidy set by the domestic government. The existence and uniqueness of signalling equilibrium in games of incomplete information with a continuum of types has been considered by Mailath (1987). He shows that if the signalling agent's payoff function satisfies certain regularity conditions (most importantly *belief monotonicity*, *type monotonicity*, and *single crossing*) then there exists a unique signalling equilibrium. In the game of section two the domestic government's welfare (payoff) function satisfies all these conditions. *Belief monotonicity* is satisfied since $\partial W_1/\partial \hat{c}_1 < 0$ for any positive export subsidy. This says that the domestic government would always like the foreign firm to believe that the domestic firm has low costs. *Type monotonicity* is satisfied since $\partial^2 W_1/\partial c_1 \partial e_1 < 0$. This says that the lower is domestic marginal cost then the larger is the gain to the domestic country from using an export subsidy, which is obviously related to the result of de Meza (1986). *Single crossing*, which is a technical

condition, is also satisfied since $(\partial W_1/\partial e_1)/(\partial W_1/\partial \hat{c}_1)$ is monotonic in domestic marginal cost for any positive export subsidy. Hence, the game of incomplete information in section two has a unique signalling equilibrium.

To derive the signalling equilibrium of the game let the signalling equilibrium export subsidy be $e_1^S = \phi_1(c_1)$, where ϕ_1 is a differentiable and one-to-one function of domestic marginal cost. The signalling equilibrium export subsidy function is derived using the incentive compatibility condition. Incentive compatibility requires that if the domestic firm has marginal cost c_1 then the domestic government maximises its welfare, given the beliefs of the foreign firm, by setting an export subsidy $e_1^S = \phi_1(c_1)$. The beliefs of the foreign firm about the marginal cost of the domestic firm are a function of the export subsidy set by the domestic government, and are obtained by inverting the signalling equilibrium export subsidy function to get $\hat{c}_1(e_1) = \phi_1^{-1}(e_1)$. Hence, incentive compatibility implies that for any value of domestic marginal cost c_1, $e_1^S = \phi_1(c_1)$ maximises $W_1(e_1, c_1, \hat{c}_1(e_1))$ where $\hat{c}_1(e_1) = \phi_1^{-1}(e_1)$. The first order condition for welfare maximisation is

$$\frac{dW_1}{de_1} = \frac{\partial W_1}{\partial e_1} + \frac{\partial W_1}{\partial \hat{c}_1}\frac{d\hat{c}_1}{de_1} = 0 \qquad (9)$$

The first term is the usual profit-shifting effect and the second term is the signalling effect of the export subsidy.

In a signalling equilibrium the foreign firm correctly infers the marginal cost of the domestic firm from the export subsidy set by the domestic government so $\hat{c}_1 = c_1$ and $\hat{B}_1 = B_1$ in equilibrium. Then, by noting that

$d\hat{c}_1/de_1 = (d\phi_1/dc_1)^{-1}$ equation (9) can be re-arranged to yield the following differential equation

$$\frac{d\phi_1}{de_1} = \frac{B_1 + \phi_1}{B_1 - 8\phi_1} \tag{10}$$

The signalling equilibrium export subsidy function, ϕ_1, must satisfy this differential equation and the initial value condition. The initial value condition comes from the fact that if the domestic firm has marginal cost c_1^H then the domestic government has no incentive to signal the competitiveness of its firm and will use the complete information export subsidy, $e_1^H = B_1^H/8$ given by (8) where $B_1^H = 2\alpha - 4c_1^H + 2c_2$. Thus, the initial value condition is $\phi_1(c_1^H) = B_1^H/8$.

To solve the differential equation it is more convenient to express the export subsidy as a function of the competitiveness rather than the marginal cost of the domestic firm, so let $e_1^S = \phi_1(c_1) = \psi_1(B_1)$. Then, in terms of this new function the initial value condition is $\psi_1(B_1^H) = B_1^H/8$ and since $d\phi_1/dc_1 = -4\, d\psi_1/dB_1$ the differential equation becomes

$$-4\,\frac{d\psi_1}{dB_1} = \frac{B_1 + \psi_1}{B_1 - 8\psi_1} \tag{11}$$

This is a first order homogeneous differential equation, and can be solved by transforming it into a separable differential equation by introducing the new variable $Z_1 = \psi_1/B_1$. This yields the following differential equation

$$\frac{dZ_1}{dB_1} = \frac{1}{4B_1} \frac{32Z_1^2 - 5Z_1 - 1}{1 - 8Z_1} \tag{12}$$

Then, separating the variables and integrating both sides yields an implicit solution given by

$$B_1^2(32Z_1^2 - 5Z_1 - 1)\left|\frac{64Z_1 - 5 + 3\sqrt{17}}{64Z_1 - 5 - 3\sqrt{17}}\right|^{1/\sqrt{17}} = K_1 \tag{13}$$

Where K_1 is the constant of integration which is obtained from the initial value condition, $\psi_1(B_1^H) = B_1^H/8$ so $Z_1(B_1^H) = 1/8$. Thus, using the initial value condition in (13), the constant of integration is given by

$$K_1 = \frac{-9}{8}(B_1^H)^2\left(\frac{3\sqrt{17} + 3}{3\sqrt{17} - 3}\right)^{1/\sqrt{17}} \tag{14}$$

Although in general it is not possible to get an explicit solution for the signalling equilibrium export subsidy, there is one special case where an explicit solution can be obtained. This occurs when the competitiveness of the highest cost type of domestic firm happens to be zero ($B_1^H = 0$) then the signalling equilibrium export subsidy is linear in the competitiveness of the domestic firm.

The competitiveness of the highest cost type of firm will be zero if the firm has a sufficiently high marginal cost, $B_1^H = 0$ if $c_1^H = (\alpha + c_2)/2$, then with complete information this firm would receive a zero export subsidy and export zero output. In the game of incomplete information the initial value condition requires the signalling equilibrium export subsidy given to the

highest cost type of firm to be equal to the export subsidy it would receive under complete information, so $\psi_1(0) = e_1^*(0) = 0$. Then from (14) the constant of integration is zero, $K_1 = 0$, and from (13) the solution is given by the positive root of the quadratic $32Z_1^2 - 5Z_1 - 1 = 0$, which is $Z_1 = (5 + 3\sqrt{17})/64$.[4] Thus, the signalling equilibrium export subsidy as a function of the competitiveness of the domestic firm is

$$e_1^S = \psi_1(B_1) = \left(\frac{5 + 3\sqrt{17}}{64}\right)B_1 = \left(\frac{5 + 3\sqrt{17}}{8}\right)e_1^* \qquad (15)$$

The signalling equilibrium export subsidy is a linear function of the competitiveness of the domestic firm, and is shown in figure one together with the profit-shifting export subsidy under complete information. It can be seen that signalling leads to an increase in the export subsidy used by the domestic government. Since $(5 + 3\sqrt{17})/8 \approx 2{\cdot}17$, the export subsidy in the signalling equilibrium under incomplete information is more than twice as large as the profit-shifting export subsidy under complete information. This leads to the following proposition:

Proposition 1. *The export subsidy in the linear signalling equilibrium under incomplete information is more than twice as large as the profit-shifting export subsidy under complete information.*

In the general case it is not possible to obtain an explicit solution for the signalling equilibrium export subsidy function, but qualitative analysis of the differential equation (12) or numerical solution of equation (13) allows a description of the general solution. The phase diagram for the differential equation in (12) is shown in figure two. The

values of Z_1 where $dZ_1/dB_1 = 0$ are given by the positive and negative roots of the quadratic $32Z_1^2 - 5Z_1 - 1 = 0$. The positive root corresponds to the linear signalling equilibrium discussed above, and the negative root corresponds to the degenerate equilibrium mentioned in footnote 1. From the initial condition $Z_1 = 1/8$ at $B_1 = B_1^H$, and from (12) the derivative dZ_1/dB_1 is unbounded at this point. There are two possible solutions shown in figure two, one that approaches the positive root and one that approaches the negative root, but the latter solution can be eliminated since it does not satisfy the second order conditions for welfare maximisation.[5] Thus, the unique solution that satisfies incentive compatibility is the one which approaches the positive root of the quadratic as B_1 increases. From figure two it is possible to plot the signalling equilibrium export subsidy as a function of the competitiveness of the domestic firm and this is shown in figure three. The signalling equilibrium export subsidy is equal to the complete information export subsidy at B_1^H and its derivative is unbounded at this point. This ensures that the domestic government has no incentive to deviate from giving the complete information export subsidy to the highest cost type of domestic firm, because an increase in the export subsidy has no effect on the inference of the foreign firm about domestic marginal cost.[6] As the competitiveness of the domestic firm, B_1, increases then the signalling equilibrium export subsidy approaches the linear solution. From figure three it is clear that signalling leads the domestic government to use a larger export subsidy than under complete information. The following proposition summarises the results in both the linear and non-linear cases:

Proposition 2. *The signalling equilibrium export subsidy under incomplete*

information is larger than the profit-shifting export subsidy under complete information.

At the second stage of the game the two firms have complete information about costs, but the domestic firm receives an export subsidy which is larger than the optimal export subsidy under complete information. Therefore, welfare of the domestic country in the signalling equilibrium is lower than welfare under complete information. Signalling involves a cost to the domestic country since it has to use an export subsidy which is larger than the optimal export subsidy under complete information so as to make its signal credible.

4. The Simultaneous Signalling Equilibrium[7]

In the previous section the foreign firm had incomplete information about domestic marginal cost but the domestic firm has complete information about foreign marginal cost, and only the domestic government used an export subsidy. In this section both firms have incomplete information about their competitor's marginal cost, and both governments can use an export subsidy to signal the competitiveness of their firm. This is now a simultaneous signalling game similar to those considered by Mailath (1988, 1989). The model and notation are the same as in the previous sections, except that the marginal cost of the foreign firm is not common knowledge and the foreign government uses an export subsidy. The domestic firm and government do not know the marginal cost of the foreign firm, c_2, but they know that it is continuously distributed with support on $[c_2^L, c_2^H]$. The foreign government gives its firm an export subsidy of e_2 per unit exported, which

is common knowledge at the second stage of the game.

Again the game is solved by a process of backward induction. The first step is to consider the second stage when firms make their output decisions given the domestic and foreign export subsidies and their beliefs about their rival's marginal cost. The expected profits of the domestic and foreign firms are

$$\begin{aligned} \pi_1 &= E_1\left[(P - c_1 + e_1)q_1 | e_2\right] \\ \pi_2 &= E_2\left[(P - c_2 + e_2)q_2 | e_1\right] \end{aligned} \tag{16}$$

The first order conditions for a Bayesian-Cournot-Nash equilibrium are

$$\begin{aligned} \partial\pi_1/\partial q_1 &= \alpha - 2q_1 - E_1(q_2|e_2) - c_1 + e_1 = 0 \\ \partial\pi_2/\partial q_2 &= \alpha - E_2(q_1|e_1) - 2q_2 - c_2 + e_2 = 0 \end{aligned} \tag{17}$$

To solve for the expected quantities take expectations of (17) and use common knowledge to obtain

$$\begin{aligned} E_2(q_1|e_1) &= (\alpha - 2\hat{c}_1(e_1) + \hat{c}_2(e_2) + 2e_1 - e_2)/3 \\ E_1(q_2|e_2) &= (\alpha + \hat{c}_1(e_1) - 2\hat{c}_2(e_2) - e_1 + 2e_2)/3 \end{aligned} \tag{18}$$

Using (18) in (17) and solving for the equilibrium quantities yields

$$q_1 = (\hat{B}_1 + 4e_1 - 2e_2)/6$$

$$q_2 = (\hat{B}_2 - 2e_1 + 4e_2)/6 \qquad (19)$$

Where $\hat{B}_1 = 2\alpha - 3c_1 - \hat{c}_1 + 2\hat{c}_2$ and $\hat{B}_2 = 2\alpha + 2\hat{c}_1 - 3c_2 - \hat{c}_2$ are measures of the competitiveness of the domestic and foreign firms given beliefs about costs. Using (19) in (1) yields the expected price-cost margins of the domestic and foreign firm

$$E_1(P - c_1) = (\hat{B}_1 - 2e_1 - 2e_2)/6$$

$$E_2(P - c_2) = (\hat{B}_2 - 2e_1 - 2e_2)/6 \qquad (20)$$

Domestic (foreign) welfare is expected producer surplus from exports by the domestic (foreign) firm, $W_1 = E_1[(P - c_1)q_1]$ and $W_2 = E_2[(P - c_2)q_2]$. From (19) and (20) domestic and foreign welfare can be written as

$$W_1 = E_1\left[(\hat{B}_1 - 2e_1 - 2e_2)(\hat{B}_1 + 4e_1 - 2e_2)/36\right]$$

$$W_2 = E_2\left[(\hat{B}_2 - 2e_1 - 2e_2)(\hat{B}_2 - 2e_1 + 4e_2)/36\right] \qquad (21)$$

To derive the simultaneous signalling equilibrium let the equilibrium export subsidy functions for the domestic and foreign governments be $e_1^S = \phi_1(c_1)$ and $e_2^S = \phi_2(c_2)$ where these functions are differentiable and one-to-one. Incentive compatibility requires that each government maximises its welfare given the marginal cost of its firm and given that beliefs are obtained by inverting the equilibrium strategies. Hence, the first order

conditions for welfare maximisation are

$$\frac{dW_1}{de_1} = \frac{\partial W_1}{\partial e_1} + \frac{\partial W_1}{\partial \hat{c}_1}\frac{d\hat{c}_1}{de_1} = 0$$

$$\frac{dW_2}{de_2} = \frac{\partial W_2}{\partial e_2} + \frac{\partial W_2}{\partial \hat{c}_2}\frac{d\hat{c}_2}{de_2} = 0 \qquad (22)$$

In a signalling equilibrium each firm correctly infers the marginal cost of its competitor from the export subsidy given to its competitor so $\hat{c}_1 = c_1$ and $\hat{c}_2 = c_2$. Then by noting that $d\hat{c}_1/de_1 = (d\phi_1/dc_1)^{-1}$ and $d\hat{c}_2/de_2 = (d\phi_2/dc_2)^{-1}$ equation (22) yields the following differential equations:

$$\frac{d\phi_1}{dc_1} = \frac{(B_1 - 2\bar{e}_2) + \phi_1}{(B_1 - 2\bar{e}_2) - 8\phi_1}$$

$$\frac{d\phi_2}{dc_2} = \frac{(B_2 - 2\bar{e}_1) + \phi_2}{(B_2 - 2\bar{e}_1) - 8\phi_2} \qquad (23)$$

Defining $B_1 - 2\bar{e}_2$ and $B_2 - 2\bar{e}_1$ as the competitiveness of the domestic and foreign firm, respectively. Where $B_1 = 2\alpha - 4c_1 + 2\bar{c}_2$, $B_2 = 2\alpha - 4c_2 + 2\bar{c}_1$, and $\bar{c}_2$ ($\bar{c}_1$) is the domestic (foreign) government's expectation of foreign (domestic) marginal cost. And $\bar{e}_2$ ($\bar{e}_1$) is the domestic (foreign) government's expectation of the foreign (domestic) export subsidy. As before it is useful to express the export subsidies as functions of competitiveness rather than marginal cost, so let $e_1^S = \phi_1(c_1) = \psi_1(B_1 - 2\bar{e}_2)$ and $e_2^S = \phi_2(c_2) = \psi_2(B_2 - 2\bar{e}_1)$. Then the two differential equations become:

$$-4\,\frac{d\psi_1}{d(B_1-2\bar{e}_2)} = \frac{(B_1-2\bar{e}_2)+\psi_1}{(B_1-2\bar{e}_2)-8\psi_1}$$

$$-4\,\frac{d\psi_2}{d(B_2-2\bar{e}_1)} = \frac{(B_2-2\bar{e}_1)+\psi_2}{(B_2-2\bar{e}_1)-8\psi_2} \qquad (24)$$

The initial value conditions are that $\psi_1(B_1^H-2\bar{e}_2) = (B_1^H-2\bar{e}_2)/8$ and $\psi_2(B_2^H-2\bar{e}_1) = (B_2^H-2\bar{e}_1)/8$, where $B_1^H = 2\alpha - 4c_1^H + 2\bar{c}_2$ and $B_2^H = 2\alpha - 4c_2^H + 2\bar{c}_1$. These two differential equations are identical to the differential equation in (10) except for the change of variables, and hence can be solved using the same method to obtain a similar solution. To determine the expected values of the domestic and foreign export subsidies, $\bar{e}_1$ and $\bar{e}_2$, take expectations of the export subsidy functions

$$\bar{e}_1 = E_2\left[\psi_1(B_1-2\bar{e}_2)\right]$$

$$\bar{e}_2 = E_1\left[\psi_2(B_2-2\bar{e}_1)\right] \qquad (25)$$

The equilibrium export subsidy functions must satisfy the two differential equations in (24) together with the initial value conditions and the two simultaneous equations in (25).

When both governments simultaneously use export subsidies to signal the competitiveness of their firms there are two effects: the *direct signalling effect* and the *strategic interaction effect*. The domestic signalling equilibrium export subsidy is a function of the competitiveness of the domestic firm, $e_1^S = \psi_1(B_1-2\bar{e}_2)$. Thus, for a given value of the expected

foreign export subsidy, $\bar{e}_2$, the direct signalling effect leads the domestic government to use a larger export subsidy than under complete information as in section three. The strategic interaction effect arises because the direct signalling effect will also lead the foreign government to increase its export subsidy. This will increase $\bar{e}_2$ and reduce the competitiveness of the domestic firm which will lead the domestic government to reduce its export subsidy. This is because domestic and foreign export subsidies are strategic substitutes, see Collie (1991). Hence, the strategic interaction effect partly offsets the direct signalling effect, so that the overall effect is less than in the one-sided signalling game of section three. The following proposition summarises the results of this section:

Proposition 3. *In the simultaneous signalling game, the strategic interaction effect partly offsets the direct signalling effect.*

5. Pooling Equilibria

For the game of section three with one-sided incomplete information there are pooling and a continuum of partial pooling equilibria as well as the unique signalling equilibrium. In a pooling equilibrium the domestic government sets an export subsidy which does not depend upon the competitiveness of the domestic firm, and hence the foreign firm cannot infer the competitiveness of the domestic firm from the domestic export subsidy. The foreign firm will then have to make its output decisions given its prior beliefs about the marginal costs of the domestic firm. Since using export subsidies to signal competitiveness involves a cost to the domestic country it is possible that it would be better off in a pooling

equilibrium.

In a pooling equilibrium no information is revealed to the foreign firm so its beliefs are that $\hat{c}_1 = \bar{c}_1$. The natural pooling equilibrium to look at is the one where the domestic government behaves as if it did not observe domestic marginal cost, but that it does know the distribution of possible costs. Then, the domestic government will maximise the expected value of welfare (7) given its prior beliefs about the distribution of costs. The pooling equilibrium export subsidy is then given by $e_1^P = \bar{B}_1/8$, where $\bar{B}_1 = 2\alpha - 4\bar{c}_1 + 2c_2$. This pooling equilibrium is supported by beliefs such that if any other subsidy is observed then the domestic firm must have the highest possible costs, $\hat{c}_1 = c_1^H$. Welfare in the pooling equilibrium may be obtained by substituting the pooling equilibrium export subsidy into domestic welfare (11), and noting that $\hat{c}_1 = \bar{c}_1$ in equilibrium. After some simplification this yields:

$$W_1^P = (2B_1^2 + B_1(\bar{B}_1 - B_1))/36 \qquad (26)$$

Welfare with an optimal export subsidy under complete information is $W_1^* = B_1^2/32$, so welfare in the pooling equilibrium is equal to welfare under complete information at $B_1 = \bar{B}_1$, $W_1^P(\bar{B}_1) = W_1^*(\bar{B}_1)$. Since signalling is costly, welfare in the signalling equilibrium is lower than welfare under complete information, $W_1^S(B_1) < W_1^*(B_1)$. Hence, at $B_1 = \bar{B}_1$ welfare in the pooling equilibrium is higher than welfare in the signalling equilibrium, $W_1^P(\bar{B}_1) > W_1^S(\bar{B}_1)$, so locally around $B_1 = \bar{B}_1$ the pooling equilibrium yields a higher level of welfare than the signalling equilibrium. Therefore, it is possible that for some distributions of costs the pooling equilibrium

welfare dominates the signalling equilibrium as shown in figure four.[8] Therefore, the domestic government may be better off not using its information about the domestic firm's marginal cost.

6. Conclusions

It has been shown that when the foreign firm has incomplete information about the marginal cost of the domestic firm then the domestic government can use an export subsidy to signal the competitiveness of its firm. A larger export subsidy leads the foreign firm to infer that the domestic firm has lower costs, and in response it reduces its output which increases the profits of the domestic firm. In the signalling equilibrium under incomplete information the domestic firm receives a larger export subsidy than it would under complete information. When both firms have incomplete information about their rival's costs then both governments have an incentive to use export subsidies to signal the competitiveness of their firm.

The signalling effect of an export subsidy is driven by its profit-shifting effect and, in particular, by the fact that the more competitive is the domestic firm then larger will be the export subsidy given by the domestic government. Therefore the signalling argument for an export subsidy is subject to the same criticisms as the profit-shifting argument, and is likely to be equally sensitive to changes to the basic model. Dixit (1984) has shown that when there are a sufficiently large number of domestic firms then the optimal policy is an export tax rather than a subsidy, because the usual terms-of-trade effect will dominate the profit-shifting effect. Then

the optimal export tax is increasing in the competitiveness of the domestic industry and, under incomplete information, the domestic government would give a *larger* export tax to signal the competitiveness of the domestic industry.

For a Bertrand duopoly Eaton and Grossman (1986) have shown that the optimal policy is an export tax rather than a subsidy, and it can be shown that the optimal export tax for the domestic country is increasing in the competitiveness of the domestic firm. With incomplete information in a Bertrand duopoly, the domestic firm would like the foreign firm to believe that it has high costs since then the foreign firm would set a high price which would increase the profits of the domestic firm. Hence the domestic government should *reduce* its export tax to signal that the domestic firm is uncompetitive.

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Footnotes

[1]The argument for strategic export subsidies is very sensitive to changes in the assumptions of the model. Dixit (1984) shows that with more than one domestic firm an export tax may be optimal due to the usual terms of trade effect, and Eaton and Grossman (1986) show that if there is Bertrand competition rather than Cournot competition then the optimal policy is usually an export tax.

[2]Bagwell and Staiger (1989) consider the use of export subsidies as signals to consumers of product quality in a model where the foreign firm faces no competition from domestic producers.

[3]This requires that the domestic government can *either* observe the marginal cost of the domestic firm *or* design some mechanism so that the domestic firm will truthfully reveal its marginal cost. The design of incentive compatible export subsidy schemes to truthfully reveal the marginal cost of the domestic firm is a current topic of research.

[4]The negative root of the quadratic gives a "degenerate" sequential equilibrium of the game where the domestic government imposes an export tax which is increasing in the competitiveness of the domestic firm. This outcome can be eliminated by stronger equilibrium refinements, and in the non-linear case it can be ruled out by the second order conditions for welfare maximisation.

[5]For details about the second order conditions in signalling games see Mailath (1987), page 1355.

[6]In the linear signalling equilibrium, the domestic government has no incentive to deviate from giving the complete information export subsidy since price is equal to marginal cost for the highest cost type of domestic firm.

[7]For an analysis of the Nash equilibrium in profit-shifting export subsidies under complete information see Collie (1991).

[8]Andersen and Hviid (1991) derive a similar result in a model of price-setting with private information. In their model the dominance of pooling over separating implies price stickiness.

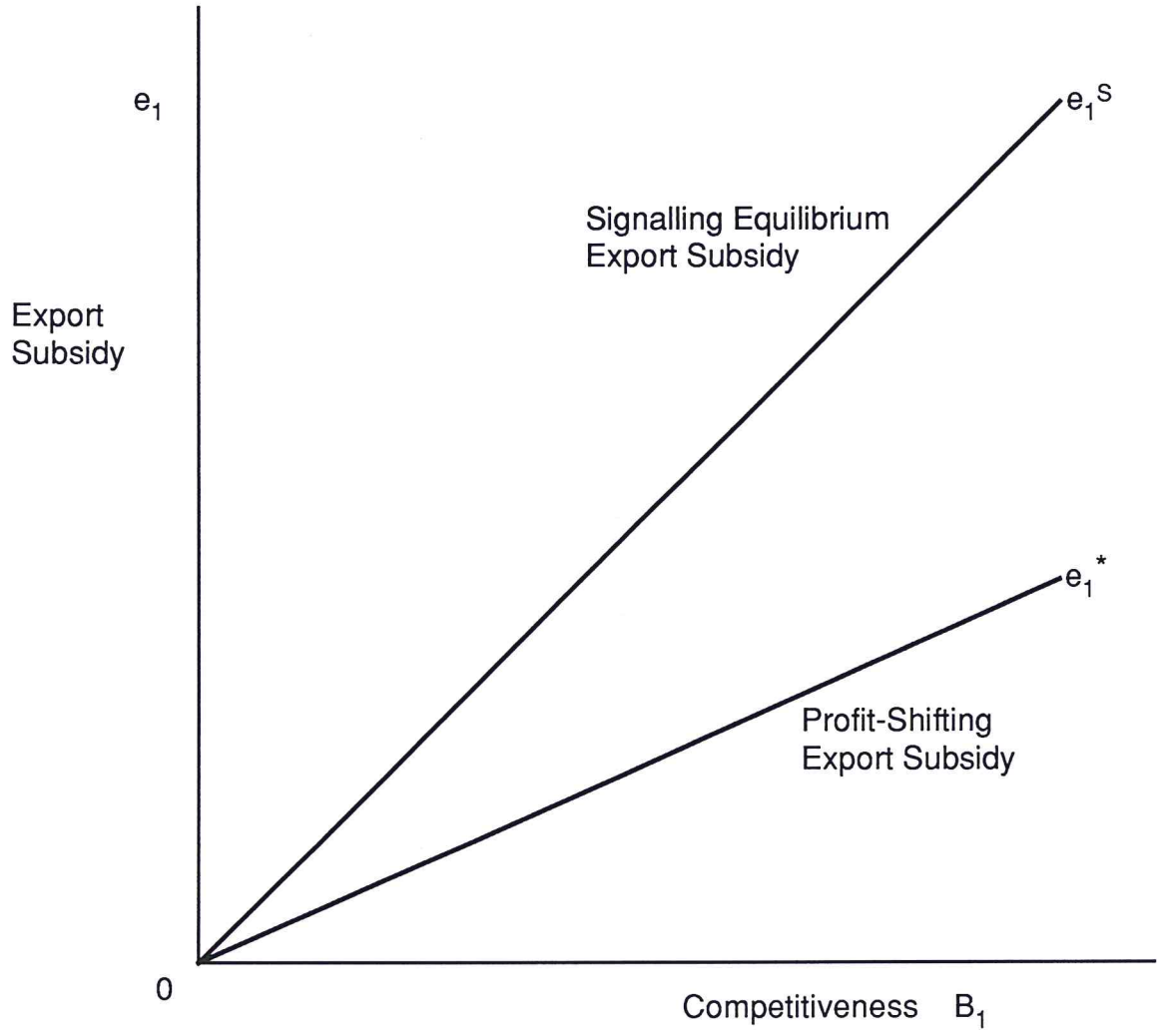

Figure One: Linear Signalling Equilibrium

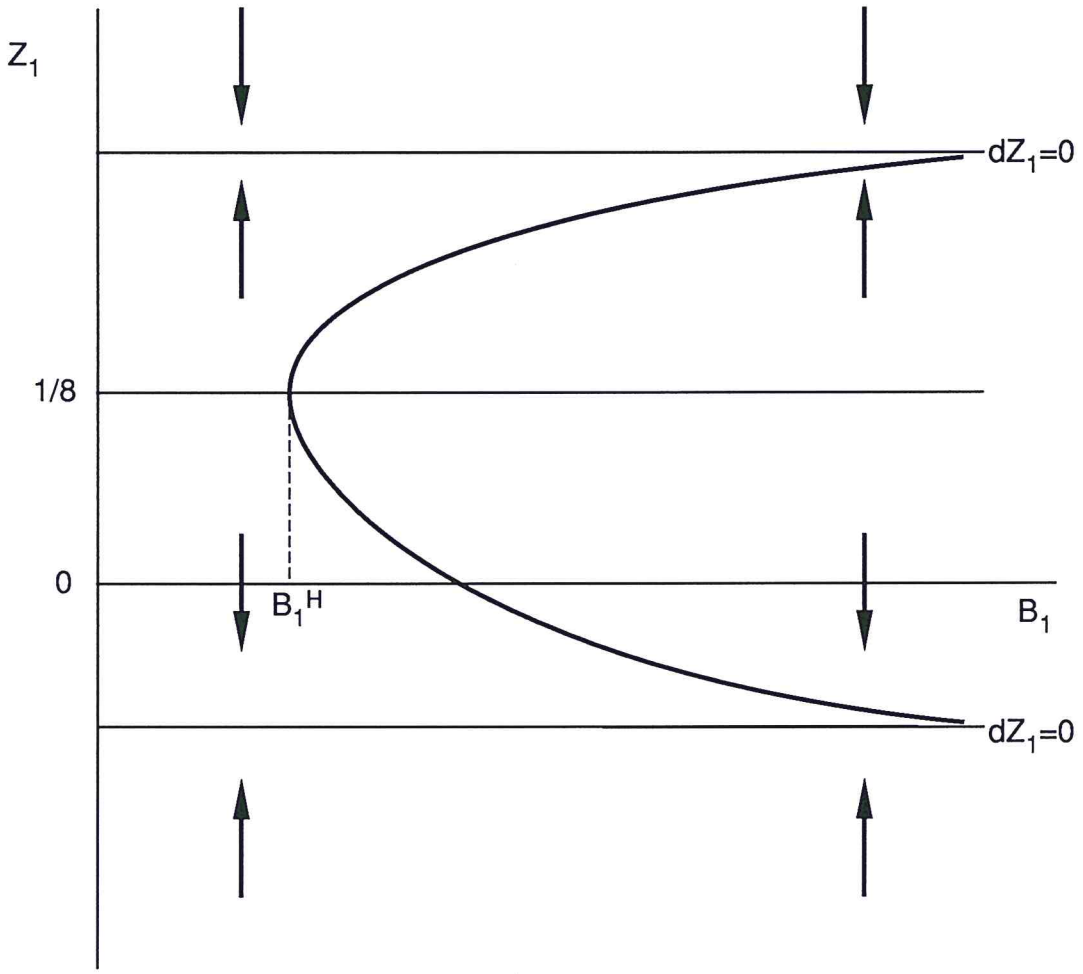

Figure Two: Phase Diagram

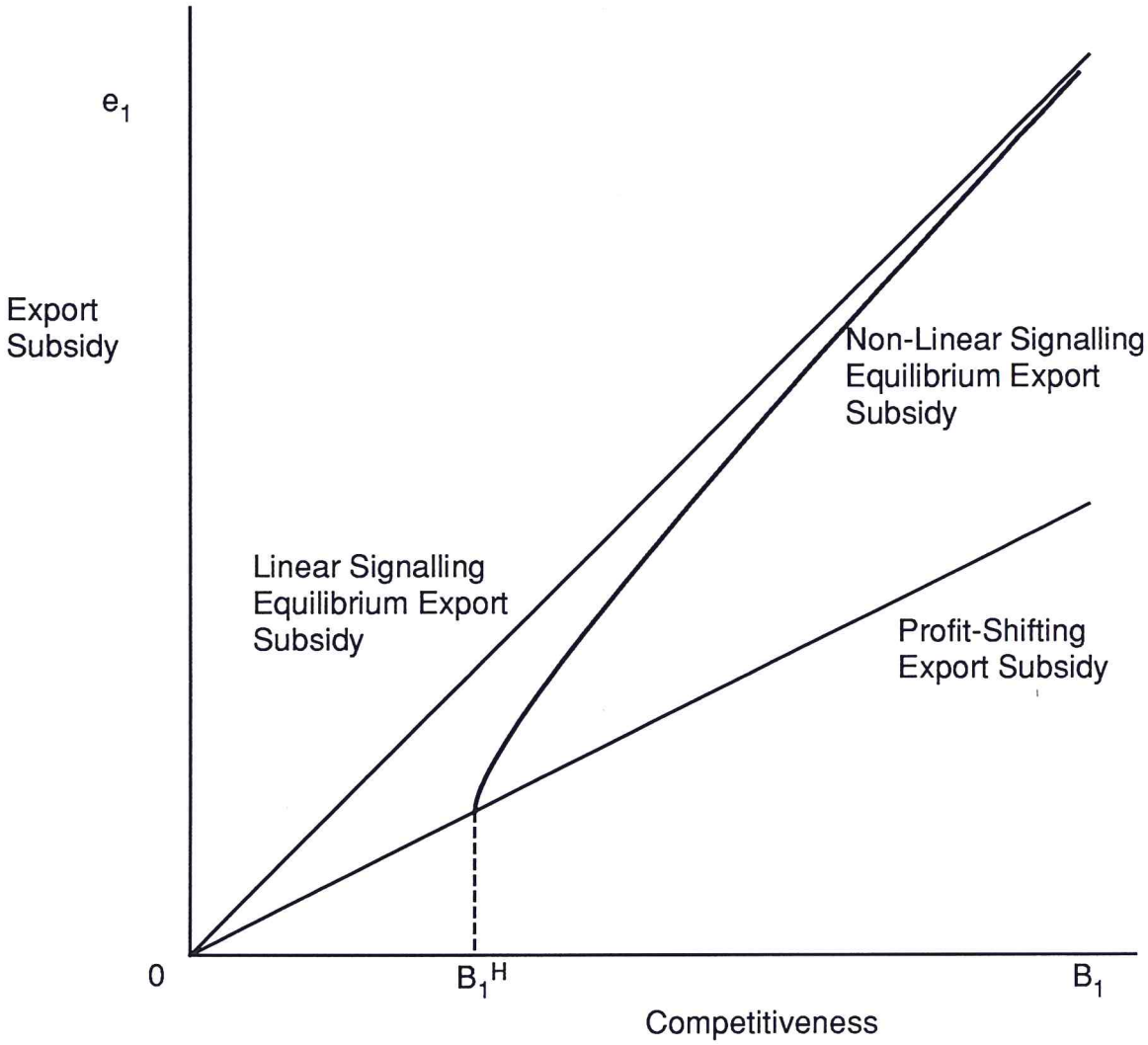

Figure Three: Signalling Equilibrium Export Subsidy

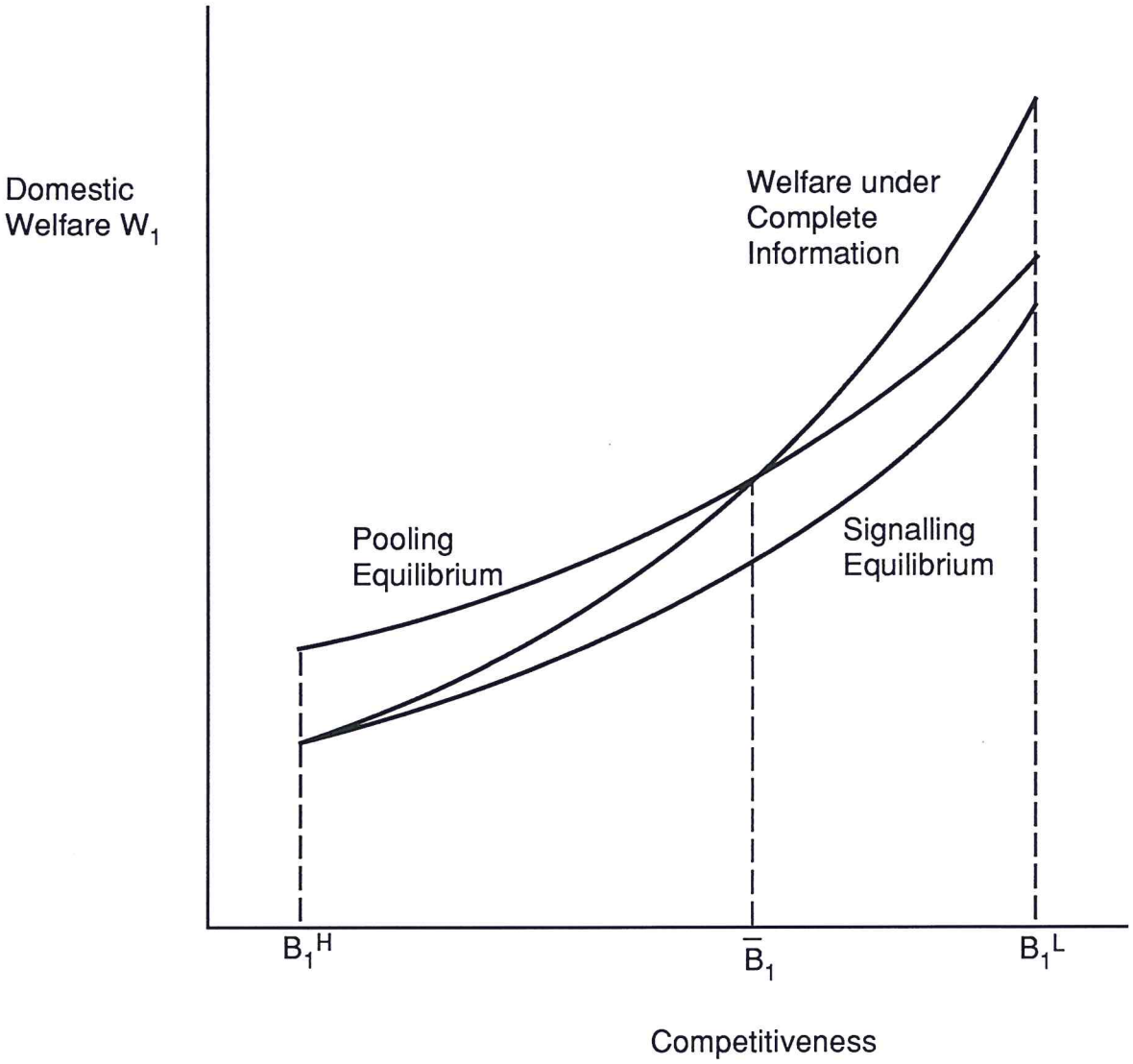

Figure Four: Pooling Equilibrium