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## TRADE AND PROTECTION IN VERTICALLY RELATED MARKETS

A domestic firm is partially dependent on a foreign vertically integrated supplier for a key intermediate product when both firms are Cournot competitors in the market for the final product. The foreign supplier generally charges its domestic rival a price for the input that exceeds the independent monopoly level and vertical foreclosure may occur. Domestic policies applied to the vertically related products can increase domestic welfare by reducing the price and increasing the availability of imported supplies of the input. Vertical integration in the foreign supplier has significant implications for all three domestic policies considered: a tariff or subsidy on imports of both products and a domestic production subsidy. The foreign vertically integrated firm tends to reduce its price for the input in response to an import tariff on the final product, whereas a simple monopoly supplier would respond by increasing its export price.

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1. Introduction

Vertically integrated firms in different countries may face substantial differences in their costs of production of a key intermediate product. These international differences can be at least partly offset if higher cost firms can reduce their costs by importing the input from abroad. However, the vertical relationship between the markets for intermediate and final products suggests that a vertically integrated firm producing the final product will have little incentive to reduce the costs of its rival. A notable example concerns recent U.S. policy to prevent the "dumping" of Japanese semiconductor chips, a key component of computers. This facilitated cooperation by Japanese producers so as to achieve a substantial increase in the export price of DRAM chips. Japanese firms, such as Toshiba and N.E.C., were able to increase their profits in both the semiconductor and final computer markets. The increase in the price (and general shortage of supplies) of semiconductor chips put U.S. producers of computers at a disadvantage.

High import prices for a key intermediate product are likely to lead to pressures on the government in the importing country to institute protectionist policies so as to help its domestic producers. For example, concerns about availability have lead the U.S. Defence Department to subsidize the domestic development of the new generation of semiconductor chips. This paper considers the implications of domestic trade and protection policies for the price and availability of imported supplies of intermediates as well as for domestic welfare.

We focus on the simplest case: a single foreign vertically integrated firm exports the final product to the domestic country on the basis of Cournot

competition with a higher cost domestic firm. In selecting its export strategy for the intermediate input, the foreign firm takes full account of the effect of these exports on the subsequent profits it can earn from the export of the final product. Vertical foreclosure occurs if it is not in the foreign firm's interest to supply its rival with the input. The domestic need for imported supplies arises because of underlying differences in costs. Differences in costs can naturally arise in an international context from differences in technological development and endowments of natural resources.

The consequences of vertical integration in the foreign supplier are best revealed by drawing a comparison with a market structure in which a foreign monopoly firm controls the export of the intermediate input and a separate foreign firm exports the final product. As we show, the vertically integrated firm restricts its exports of the input to such an extent that the price charged its rival exceeds the independent monopoly level.

Turning to commercial policy, we examine the implications of three instruments available to the importing country: a subsidy to the domestic production of the input, a subsidy (or tariff) on imports of the input and an import tariff on the final product. A main issue concerns the effects of these policies on the price that the domestic firm will subsequently face for imported supplies. For example, a tariff on final good imports into the domestic country increases the domestic firm's final output and its demand for supplies of the input from abroad. The response of the foreign supplier is significantly affected by vertical integration. With linear demand, a simple monopoly supplier would respond by raising the price of the input. In sharp contrast, a vertically integrated supplier increases its exports of the intermediate product by a sufficient amount to reduce the price paid by the domestic firm.

We also explore some of the welfare implications of domestic policy. A main result is that domestic welfare is always increased by a sufficiently large subsidy on intermediate imports to move the equilibrium from vertical foreclosure to vertical supply. However, if vertical supply takes place in the absence of commercial policy, domestic cost conditions can be critical in determining whether imports of the intermediate good should be taxed or subsidized. If the marginal cost of domestic production of the input is increasing (our general assumption), a subsidy on intermediate imports tends to reduce the import price paid by the domestic firm and a positive subsidy improves domestic welfare. In contrast, if domestic marginal cost is constant, the foreign supplier, whether it is vertically integrated or a simple monopoly, may choose to price the intermediate input so as just to prevent domestic entry into the production of the input. A small tariff imposed on intermediate imports then has no effect on the 'entry-deterring' price of the input and the tariff is fully effective as a device to extract foreign rent. Interestingly, in this latter case, a vertically integrated supplier and a simple monopoly supplier respond in the same way, so that vertical integration per se plays no role.

The basic model developed here to describe the actions of the vertically integrated firm is also utilized by Spencer and Jones (1989), a paper concerned with providing a general explanation of optimal policy by the exporting country. In addition, Spencer and Jones (1989) examines the conditions under which the vertically integrated firm will choose a positive level of exports of the intermediate product (vertical supply) rather than cutting off supplies altogether (vertical foreclosure)<sup>1</sup>. More recently, Rodrik and Yoon (1989) have adopted this framework with different assumptions about domestic costs. Section 7 describes some of their results in the context of our general model.

Purely competitive models incorporating intermediate goods have been part of the international trade literature for some time. Two notable papers are Dixit and Grossman (1982) and Sanyal and Jones (1982). The implications of vertically related markets for domestic tariff policy are examined in a general equilibrium purely competitive model by Jones and Spencer (1989) and some connections between their paper and the present one are discussed in the concluding remarks.

The structure of the model is described in Section 2 of the paper. Section 3 is concerned with the Cournot market for the final good and the input decision by the domestic firm. Section 4 then characterizes the market for the intermediate input either when the input is supplied by a foreign vertically integrated firm or by a foreign monopoly. The use of domestic policies to move the equilibrium from vertical foreclosure to vertical supply, and the domestic benefit from this action, are subsequently explored in Section 5. Next, given vertical supply, Section 6 examines the implications of domestic policy for the price paid by the domestic firm for foreign supplies and for domestic welfare. The special case in which the domestic marginal cost of production of the input is constant is discussed in Section 7. Finally, Section 8 contains concluding remarks.

## 2. Model Structure

A foreign vertically integrated firm, firm I, in country 1 (potentially) exports an intermediate input to its higher cost rival, firm 2, located in country 2 (the domestic country). In addition to these imports, the domestic firm has the option of producing its own supplies of the (homogeneous) input. Firm I and firm 2 are Cournot competitors in the domestic market for the final product. We abstract from the possibility that the final product is also sold in country 1. If the two markets are segmented, this involves no loss of generality.

For simplicity it is assumed that one unit of the final product can be produced from one unit of the intermediate product<sup>2</sup>. Firm I produces the intermediate product (and therefore the final product) at a constant marginal cost  $c_1$ , whereas the marginal cost,  $c_2$ , of the first unit produced by firm 2 exceeds  $c_1$ . This is a simple way of expressing the idea that the foreign firm I has a superior technology or access to a cheaper source of supply of a resource needed to produce the input. Unless otherwise stated, the domestic marginal cost of production is assumed to be strictly increasing. Although we assume that firm 2 is vertically integrated, this is not necessary. The intermediate good could be supplied by a perfectly competitive industry in the domestic country.

The subgame perfect equilibrium incorporates two stages of decision. In Stage 1, firm I commits to the quantity  $x$  of exports of the intermediate product. Firm I also sets the price  $r$  for intermediates so as to satisfy a market clearing condition at which the demand for imports by firm 2 in stage 2 is equal to the committed level  $x$ . In stage 2, firm 2 chooses the cost minimizing combination of imports  $x$  and its own supplies  $x_2$  to produce final output  $y_2$  and firm I exports the quantity  $y_1$  of the final good to the domestic country.

We have in mind a situation where export of the intermediate product takes time and where firm 2 must receive its supplies prior to its production of the final good. In setting the level of these exports in stage 1, firm I takes full account of the subsequent Cournot (quantity Nash) equilibrium in the export market for the final product, including the response of firm 2 in the production of its own supplies. Vertical supply occurs only if the export of the intermediate product increases firm I's equilibrium level of profit. This choice of  $x$  by firm I could equivalently be expressed as a choice of  $r$  in stage 1. This is legitimate since the quantity of exports  $x$  and the price  $r$  that the domestic firm

pays are related simply by the requirement that demand for  $x$  equals the supply at price  $r$ . If firm I instead chooses  $r$  in stage 1, the level of  $x$  exported is the level demanded by firm 2 at the price  $r$ . In what follows we may often refer to firm I's choice in stage 1 as involving a selection of  $r$ .

The domestic country is assumed to commit to its policies, a specific import tariff  $t$  on the final good, a specific subsidy  $s$  on intermediate imports and a specific subsidy  $\sigma$  to local production  $x_2$  at stage 0 prior to firm I's decision as to its level of sale of the input in stage 1.

### 3. The Final Goods Market

This section is concerned with the second stage equilibrium in the domestic market for the final product and the determination of the level of domestic production of the input by firm 2.

Firm I's profit from exports  $y_1$  of the final good and  $x$  of the input is

$$\pi^1 = (p-t-c_1)y_1 + (r+s-c_1)x \quad (3.1)$$

where  $p = p(Y)$  is the price of the final good and  $Y = y_1 + y_2$  represents aggregate output. Firm 2's profit from the sale of  $y_2$  is

$$\pi^2 = py_2 - rx^d - C^2(x_2) + \sigma x_2 \quad (3.2)$$

where  $x^d = y_2 - x_2 \geq 0$  represents firm 2's demand for imports of the input at price  $r$ . In equilibrium,  $x^d$  equals the quantity  $x$  supplied by firm I in stage 1.  $C^2(x_2)$  represents the total cost of production of  $x_2$  and  $\sigma x_2$  is the subsidy payment for the domestic production of the input.

We now consider firm 2's choice between importing and the use of its own supplies. Substituting for  $x^d$  in (3.2), firm 2's profit becomes

$$\pi^2 = (p-r)y_2 + (r+\sigma)x_2 - C^2(x_2) \quad (3.3)$$

Firm 2 sets the level of  $x_2$  so as to minimize total cost for a given level of output  $y_2$ . From (3.3),  $x_2$  satisfies the first order condition,

$$C_x^2(x_2) - \sigma \geq r \quad (= r \text{ if } x_2 > 0) \quad (3.4)$$

If the marginal cost of production of the first unit of  $x_2$  less any subsidy payment exceeds the import price  $r$ , then, from (3.4),  $x_2 = 0$  and firm 2 produces using imported supplies only. If  $x_2 > 0$ , the requirement that  $C_x^2(x_2) = r + \sigma$  implicitly defines the supply of  $x_2$  as an increasing function of  $r$ :  $x_2 = x^2(r + \sigma)$  where  $x_r^2 = x_\sigma^2 = 1/C_{xx}^2(x_2) > 0$ .

It is useful at this point to define  $r^p$ , the (prohibitive) import price of intermediates at which the domestic firm's demand  $x^d$  is reduced to zero and vertical foreclosure occurs. At the price  $r^p$ , firm 2 sets  $x^2(r^p + \sigma) = y_2$  and produces the final good using only domestic supplies of the input. If  $c_2 - \sigma > r^p$ , domestic production of the input is prohibitively expensive, and by setting the foreclosure price  $r^p$ , firm I enjoys a monopoly of the market for the final good.

At the (second stage) Cournot equilibrium for the final good, firm I sets its exports  $y_1$  to maximize (3.1), given  $y_2$ ,  $r$  (determined by the prior committed value of  $x$ ) and stage 0's values of  $t$ ,  $\sigma$ , and  $s$ . Similarly, firm 2 chooses  $y_2$  to maximize (3.3), given  $y_1$ ,  $r$ ,  $t$ ,  $\sigma$  and  $s$ . The first order conditions for the choice of  $y_1$  and  $y_2$  are respectively,

$$\pi_1^1(y_1, y_2, t) = p + y_1 p' - t - c_1 = 0 \quad (3.5)$$

$$\pi_2^2(y_1, y_2, r) = p + y_2 p' - r = 0 \quad (3.6)$$

Solving (3.5) and (3.6) simultaneously, we obtain the Cournot equilibrium levels of output as functions of  $r$  and  $t$ :

$$y_1 = y^1(r, t) \text{ and } y_2 = y^2(r, t) \quad (3.7)$$

Firm 2's derived demand  $x^d = x(r, t, \sigma)$  for imported supplies of the input is firm 2's output at the Cournot equilibrium less its own production of the input. In equilibrium, the demand for imports is equal to the supply and

$$x(r, t, \sigma) = y^2(r, t) - x^2(r + \sigma) = x. \quad (3.8)$$

The subsidy  $s$  on intermediate imports does not affect firm 2's demand for these imports because  $r$  is defined as the domestic price paid by firm 2. Since firm 1 receives  $r+s$  per unit of  $x$  supplied,  $s$  operates through its effect on the price  $r$  and quantity  $x$  chosen by firm 1. The subsidy  $\sigma$  to domestic production also affects final output only through its influence on the price  $r$  that the domestic firm pays for imported supplies.

Under standard conditions<sup>3</sup>, an increase in the tariff on final product imports reduces these imports, causing an expansion in the level of domestic production of the final product, but an overall fall in domestic consumption. A reduction in the price paid for intermediate imports also increases domestic production and reduces the level of imports of the final product, but, in this case, domestic consumption rises. Consumers are made better off by the fall in domestic production costs. Of special interest in what follows is the case of linear demand, where, from total differentiation of (3.5) and (3.6),

$$y_t^1(r,t) = 2/3p' < 0, \quad y_t^2(r,t) = -1/3p' > 0 \quad \text{and} \quad Y_t(r,t) = 1/3p' < 0 \quad (3.9)$$

and,

$$y_r^1(r,t) = -1/3p' > 0, \quad y_r^2(r,t) = 2/3p' < 0 \quad \text{and} \quad Y_r(r,t) = 1/3p' < 0. \quad (3.10)$$

From (3.8), an increase in  $r$  reduces the derived demand for  $x$  both because it decreases firm 2's final output and because firm 2 then uses more domestic supplies:

$$x_r(r,t,\sigma) = y_r^2(r,t) - x_r^2(r+\sigma) < 0. \quad (3.11)$$

Imports of the intermediate product are reduced to zero at  $r = r^p$ .

The foreclosure price  $r^p$  is affected by both the domestic policies  $t$  and  $\sigma$ . Setting  $x = 0$ , (3.8) implicitly defines<sup>4</sup>  $r^p(t,\sigma)$  as a function of  $t$  and  $\sigma$  with partial derivatives,

$$r_t^p = -y_t^2/x_r > 0 \quad \text{and} \quad r_\sigma^p = x_\sigma^2/x_r < 0. \quad (3.12)$$



A higher final goods tariff causes the domestic firm to expand its output, increasing its demand for intermediate imports. A greater value of  $r^p$  is then required to reduce these imports to zero. As for the production subsidy, an increase in  $\sigma$  reduces the foreclosure price  $r^p$  by encouraging domestic production of the input.

#### 4. Strategic Choice of Intermediates Exports

We turn now to the choice made by the foreign vertically integrated firm in stage 1 concerning its level of exports of the intermediate product, or equivalently, its choice of the price at which to supply its domestic rival. Firm I's profit from the two export markets can be written as:

$$\pi^I(r, t, \sigma, s) = (r+s-c_1)x(r, t, \sigma) + (p-t-c_1)y^1(r, t). \quad (4.1)$$

Firm I makes its selection of  $x$  (which equals  $x(r, t, \sigma)$ ) or  $r$  to maximize profit<sup>5</sup>, taking full account of the effect of this choice on equilibrium values at the second stage.

Firm I supplies its rival with the input if a reduction in  $r$  below the foreclosure price would increase its overall profits: i.e. if

$$\pi_r^I(r^p, t, \sigma, s) < 0 \text{ at } r = r^p. \quad (4.2)$$

If  $\pi_r^I(r^p, t, \sigma, s) \geq 0$ , firm I chooses vertical foreclosure. At a vertical supply equilibrium, from (4.1) and (3.5), firm I sets the price  $r^I$  for the input to satisfy

$$\pi_r^I(r^I, t, \sigma, s) = x + (r^I+s-c_1)x_r + y_1 p' y_r^2 = 0 \quad (4.3)$$

Condition (4.3) implicitly defines the price of imported supplies as a function  $r^I(t, \sigma, s)$  of domestic policies  $t$ ,  $\sigma$  and  $s$ .

The strategic interaction between the two export markets is captured by the assumption that the foreign vertically integrated firm jointly controls the export of both the intermediate and final products. As a benchmark for comparison, we consider an alternative market structure in which a foreign

monopoly supplier, firm M, controls exports of the intermediate product and an independent foreign firm exports the final good. The intermediate product is assumed to be available at a constant marginal cost,  $c_1$ , to both firm M and the independent firm exporting the final good.<sup>6</sup> There is no change in the sequence of decisions or in the second stage relationships, but firm M is concerned only with the profit from the export of intermediates given by the first term of (4.1). At the profit maximum, firm M's price  $r^M$  for intermediates satisfies the standard first order condition for a monopoly,

$$\pi_r^M(r^M, t, \sigma, s) = x + (r^M + s - c_1)x_r = 0 \quad (4.4)$$

Assuming the second order condition holds, (4.4) implicitly defines the monopoly input price as a function  $r^M(t, \sigma, s)$  of  $t$ ,  $\sigma$  and  $s$ . Firm M exports the quantity  $x^M = x(r^M, t, \sigma)$  of the intermediate input at stage 1.

A comparison of (4.3) with (4.4) reveals that the third term,  $y_1 p' y_r^2$ , in (4.3), represents the 'strategic' effect of the price  $r$  charged for intermediates on the profits earned by the foreign vertically integrated firm from the export of the final product at the second stage. An increase in the price charged the domestic firm for imported supplies reduces domestic production of the final product, increasing the price that firm I receives for its final exports. From (3.5), this strategic term can be separated into two parts, a terms of trade effect and a volume of trade effect of the input price  $r$  on the market for the final product:

$$y_1 p' y_r^2 = y_1 dp/dr + (p - t - c_1) y_r^1 \quad (4.5)$$

Since  $dp/dr = p' Y_r > 0$  and  $y_r^1 > 0$ , raising  $r$  raises both terms of trade ( $r$  and  $p$ ) as well as the volume of exports of the final good.

As shown in Proposition 1, the strategic effect of the input price on exports of the final product gives firm I an incentive to increase this price

above the independent monopoly level. For this result to hold, exports of the final product must be strictly positive. If there are no exports of the final product, due say to a prohibitive tariff, denoted  $t^*$ , on final product imports, firm I becomes identical to firm M. Since a foreign monopoly supplier will not cut off supplies entirely, Proposition 1 applies whether or not firm I chooses to engage in vertical foreclosure.

**Proposition 1**

The foreign vertically integrated firm charges its domestic rival a price for the input that exceeds the independent monopoly level:

$$r^I(t, \sigma, s) > r^M(t, \sigma, s) \text{ for } t < t^*.$$

Proof: From (4.3) and (4.4), if  $t < t^*$  we have  $\pi_I^I(r^M, t, \sigma, s) = y_1 p' y_F^2 > 0$  at  $r = r^M$ . Since  $\pi_{rr}^I < 0$ , firm I's profits are increased by setting  $r^I$  above  $r^M$ . \*\*\*

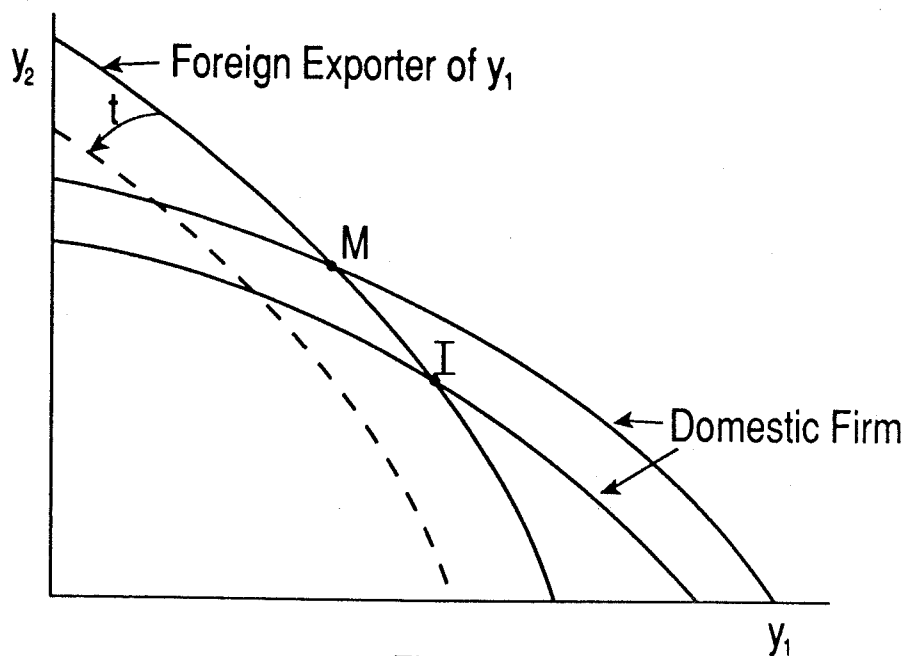


Figure 1

The fact that  $r^I$  exceeds  $r^M$  is illustrated in Figure 1. The increase in  $r$  from  $r^M$  to  $r^I$  shifts the domestic firm's reaction function in toward the origin, thus moving the Cournot equilibrium from point M to point I. As Figure 1 also

illustrates, an import tariff  $t$  on the final product serves as an instrument by which the domestic country can affect the Cournot equilibrium. An increase in  $t$  shifts the reaction function for  $y_1$  down towards the origin as shown by the dotted line in Figure 1.

The next two sections are concerned with the policy implications of a domestic dependence on the foreign vertically integrated firm for the supply of the intermediate input. The central question is whether the policy instruments  $s$ ,  $t$  and  $\sigma$  can serve to help the domestic country by increasing the quantity and reducing the price paid for imported supplies. In Section 5, we briefly examine the effects of these policies, starting from an initial situation of vertical foreclosure in which firm I supplies none of the input. In Section 6, we explore the implications of these policies under a setting of vertical supply.

##### 5. Domestic Policy and the Vertical Foreclosure Decision

Whether there is vertical foreclosure in the absence of government policy depends on the cost at which the input can be produced in the importing country. As Spencer and Jones (1989) show, a vertically integrated firm will not export the intermediate input if otherwise it would have a monopoly of the market for the final product. Even if the domestic firm can produce without the use of imported supplies, vertical foreclosure may still occur if the domestic marginal cost of production is sharply increasing. Imported supplies are then mainly used to increase domestic output rather than to substitute for the domestic production of the input.

An important aspect of policy in this situation is its effectiveness in inducing the foreign vertically integrated firm to supply the domestic rival. We first consider the most direct policy: an import subsidy  $s$  on intermediates. If domestic production of the input is prohibitively expensive ( $x_2 = 0$ ), then from

(4.2), (4.3) and (3.5), firm I sets  $r < r^p$  if

$$\pi_I^I(r^p, t, \sigma, s) = (r^p + s - c_1 - (p - t - c_1))y_I^2 < 0. \quad (5.1)$$

Thus a small reduction in  $r$  below the foreclosure price increases firm I's profit whenever firm I earns a higher profit margin from the export of the intermediate than the final product. With no domestic production of the input, the domestic firm starts producing the final product at any price for imported supplies below the price of the final product (after entry). As a consequence, vertical foreclosure requires an input price  $r^p$  equal to the price  $p$  of the final product (see (3.6) with  $y_2 = x_2 = 0$ ). Substituting  $r^p = p$  into (5.1), the foreign firm supplies its rival with the input whenever  $\pi_I^I = (s+t)y_I^2 < 0$ . It follows immediately that, in the absence of domestic production of the input, any small positive subsidy on intermediate imports (or indeed any small import tariff on the final product) will induce vertical supply. By exporting the intermediate product, the foreign vertically integrated firm supports the entry of the domestic firm as a rival producer of the final product.

If domestic production is profitable without imported supplies, then the input price at which foreclosure occurs is strictly less than the price of the final product. This follows since, from (3.6), the domestic firm produces where marginal revenue is equal to  $r^p$  and, with positive production levels, marginal revenue is strictly less than price. A higher subsidy  $s$  is then needed to make it profitable for the foreign vertically integrated firm to supply the input. At a sufficiently high value of  $s$ , condition (4.2) for vertical supply is satisfied<sup>7</sup>. These results are reported in Proposition 2.

**Proposition 2**

(i) With no domestic production of the input, a small subsidy on intermediate imports will induce vertical supply by the foreign vertically integrated firm and

the entry of the domestic firm as a producer of the final product.

(ii) With domestic production of the input, a sufficiently large subsidy on intermediate imports will induce the foreign vertically integrated firm to supply its domestic rival with the input.

Starting from an initial situation of vertical foreclosure, Proposition 3 shows that domestic welfare is always increased by a sufficiently large subsidy to intermediate imports to induce vertical supply. This result holds independently of whether it is profitable for the domestic firm to produce the input itself. Even though the required subsidy rate may be large, the subsidy payment itself is small in the neighborhood of the point at which vertical supply just occurs.

**Proposition 3**

If there is vertical foreclosure at  $t=\sigma=s=0$ , then domestic welfare is increased by a sufficiently large subsidy to intermediate imports to induce the foreign vertically integrated firm to supply the input to the domestic firm.

Proof: See Appendix A.

A tariff  $t$  on imports of the final product is also a means by which the domestic country can induce supply of the input by the foreign vertically integrated firm. In fact, as shown by Spencer and Jones (1989), both parts of Proposition 2 apply with the subsidy  $s$  replaced by the tariff  $t$ . Essentially, a tariff decreases the profit margin on sales of the final good and gives firm I an incentive to get "under" the tariff wall by supplying the intermediate product required at a lower stage of production. However, it is not necessarily optimal for country 2 to use a tariff to induce vertical supply. From the Brander and Spencer (1984a) analysis we know that the domestic country may have an incentive to use a tariff as a means of shifting rent from the foreign producer of the final product to the domestic country, but it is possible that the optimal

tariff falls short of the level needed to induce vertical supply.

In contrast with the policies  $s$  and  $t$ , a subsidy  $\sigma$  to domestic production tends to reduce the incentive for the foreign vertically integrated firm to supply its domestic rival with the input<sup>8</sup>. The subsidy reduces the foreclosure price  $r^p$  (see (3.12)) and consequently the price that the domestic firm is willing to pay for the first unit of imported supplies.

## 6. Response to Domestic Policies under Vertical Supply

For this section, we assume that we are in the region of vertical supply. The domestic policy implications of the vertically integrated structure of the foreign supplier are revealed by a comparison of the responses of firm I and firm M to policy initiatives. It is convenient to assume throughout this section that the demand curve for the final product and the domestic supply curve for the input are both linear:  $p''(Y) = 0$  and  $x_{rr}^2(r+\sigma) = 0$ . This ensures a linear derived demand curve for imports of the input. It is well known that the curvature of demand can be important for the response of imperfectly competitive firms to changes in policy, but nevertheless the linear case illustrates the general tendency under a broad class of demand functions. We first examine the effects of subsidizing the domestic production of the input.

### A. A Subsidy to Local Production

If the domestic firm does not produce the input at the subsidized equilibrium, then the subsidy  $\sigma$  to domestic production has no effect. Otherwise, from (3.8), an increase in  $\sigma$ , with  $r$  held constant, causes the domestic firm to substitute its own production  $x_2$  for imported supplies, reducing its demand for imports of the intermediate product:  $x_\sigma = -x_\sigma^2(r+\sigma) < 0$ . With the fall in demand for  $x$ , both firm I and firm M respond by reducing the price charged for the input<sup>9</sup>. From (4.3) and (4.4),

$$r_{\sigma}^I = x_{\sigma}^2 / \pi_{rr}^I < 0 \text{ and } r_{\sigma}^M = x_{\sigma}^2 / \pi_{rr}^M < 0. \quad (6.1)$$

In both cases, the quantity of intermediate imports also falls (bringing the equilibrium closer to foreclosure)<sup>10</sup>.

Nevertheless, the responses of the two firms differ in magnitude. The vertical connection between the markets gives firm I an incentive to reduce the import price for the input by more than would firm M.

**Proposition 4**

An increase in the subsidy  $\sigma$  to domestic production causes firm I to reduce the price charged the domestic firm for the input by a larger amount than would an independent monopoly supplier:

$$r_{\sigma}^I(t, \sigma, s) < r_{\sigma}^M(t, \sigma, s) < 0 \quad (6.2)$$

**Proof:** The result follows from (6.1) and  $\pi_{rr}^M = 2x_r < \pi_{rr}^I = 2x_r - p'Y_r y_r^2 < 0$ . \*\*\*

As the price of imported supplies falls (in response to an increase in  $\sigma$ ), domestic output increases, reducing firm I's exports of the final product. Consequently, the magnitude of the strategic term  $y_1 p' y_r^2$  in the first order condition (4.3) is reduced, giving firm I less of an incentive to set the input price above the monopoly level. In effect, by reducing the importance of the export market for the final product, an increase in  $\sigma$  brings firm I's behavior closer to that of a simple monopoly exporter of the intermediate product.

It is well understood that under Cournot duopolistic competition, a small production subsidy to the domestic firm increases domestic welfare, both because it shifts profit from the foreign to the domestic firm and because it reduces the price paid by domestic consumers for the final product (see Spencer and Brander (1983) and Dixit (1984)). The new consideration here is foreign imperfect competition in the supply of intermediates. That the subsidy  $\sigma$  reduces the price paid for intermediate imports adds an additional welfare benefit by further



increasing both domestic profits and domestic consumption of the final product.

**B: Subsidy on Intermediate Imports**

As might be expected, a subsidy  $s$  on intermediate imports reduces the import price  $r$  paid by the domestic firm whether the foreign supplier is vertically integrated or an independent monopoly and under general demand conditions. Exports of the intermediate input increase in both cases. The vertically integrated structure of firm I again affects the magnitude of the pricing response.

**Proposition 5**

An increase in the subsidy  $s$  to intermediate imports causes firm I to reduce the price charged the domestic firm for the input by a larger amount than would an independent monopoly supplier:

$$r_s^I(t, \sigma, s) < r_s^M(t, \sigma, s) < 0 \quad (6.3)$$

Proof: From (4.3) and (4.4),  $r_s^I = -x_r/\pi_{rr}^I < 0$  and  $r_s^M = -x_r/\pi_{rr}^M < 0$  under general demand conditions. Assuming  $p''(Y)=0$  and  $x_{rr}^2=0$ , the result then follows from  $\pi_{rr}^M = 2x_r < \pi_{rr}^I = 2x_r - p'Y_r y_r^2 < 0$  \*\*\*

The price  $r^I$  charged by firm I falls by more than  $r^M$  (in response to  $s$ ) for the same reason that we have already discussed in connection with the domestic production subsidy  $\sigma$ . The subsidy  $s$  reduces the equilibrium level of firm I's exports  $y_1$  of the final product, reducing firm I's incentive to set its price for intermediates above the monopoly level.

Starting from an initial setting of vertical supply, Proposition 6 shows that domestic welfare is increased by a small positive subsidy  $s$  independently of whether imports of the intermediate input are supplied by firm I or by firm M.

**Proposition 6**

If there is vertical supply at  $t=\sigma=s=0$ , then a small import subsidy on

intermediates supplied by either firm I or firm M increases domestic welfare.

Proof: See Appendix A.

This result contrasts with the Katrac (1977) result that domestic welfare is increased by a tariff on imports of a final product (or indeed of an intermediate product) supplied by a foreign monopolist under linear demand conditions<sup>11</sup>. With pure competition in the rest of the economy, the additional tariff revenue collected from the foreign monopoly more than offsets the loss in consumer welfare. Our case differs because of the existence of Cournot competition in the market for the final product. The subsidy  $s$  on intermediate imports reduces the import price for the input and the domestic firm's marginal costs, shifting profits from the foreign producer of the final product to the domestic firm. The welfare gain from increased domestic profit plus the consumer gain from a lower price for the final product more than offsets the cost of the subsidy paid to the foreign supplier.

This policy also benefits the foreign supplier receiving the subsidy payment. From (4.1) using (4.3), the foreign vertically integrated supplier enjoys an increase in profits given by  $d\pi^I/ds = x > 0$ . For firm I, the increased profit from intermediates exports more than offsets the fall in profit from the reduced level of exports of the final good and both countries gain. The profits of both vertically integrated firms rise and, in addition, domestic consumers benefit from a lower price for the final product.

### C. A Tariff on Imports of the Final Product

A tariff on imports of the final product shifts out the domestic firm's marginal revenue curve, increasing its demand for intermediate imports for any given price  $r$ :  $x_t = y_t^2(r, t) > 0$ . Given our assumption that demand is linear, an independent monopoly supplier would respond by increasing both the price and

supply of the intermediate product<sup>12</sup>. From (4.4), (3.8) and  $\pi_{rr}^M = 2x_r$ ,

$$r_t^M(t, \sigma, s) = -y_t^2 / \pi_{rr}^M > 0 \text{ and } dx^M/dt = y_t^2/2 > 0 \quad (6.4)$$

Now consider the effect of the tariff when firm I jointly exports both products. From (4.3),

$$r_t^I(t, \sigma, s) = -(y_t^2 + p'y_t^1 y_r^2) / \pi_{rr}^I \quad (6.5)$$

The first positive term in the numerator of (6.5) represents the effect of the tariff in increasing the derived demand for intermediate imports. As can be seen from (6.4), it is this term that leads firm M to raise its price in response to a tariff. The second negative term in the numerator of (6.5) is a consequence of the effect of the tariff in reducing the size of the "strategic" component,  $y_1 p' y_r^2$ , of the pricing rule (4.3). As was the case with both the policies  $\sigma$  and  $s$ , an increase in the tariff reduces the importance of the export market for the final product, giving firm I less of an incentive to price its exports of intermediates above the monopoly level.

In contrast with the policies  $\sigma$  and  $s$ , however, the negative effect of the tariff on the strategic component for the choice of  $r$  dominates the tendency for firm I to follow firm M's strategy of increasing the price charged for intermediates. Overall, the tariff reduces the price  $r^I$  that the domestic firm pays for imported supplies. Since the demand for imported supplies rises and the price falls, it follows that greater quantities of the input are supplied by the foreign vertically integrated firm.

**Proposition 7:**

An increase in the tariff  $t$  on imports of the final product causes firm I to reduce the price charged the domestic firm for imported supplies of the input.

**Proof:** Substituting  $y_r^2 = 2/3p'$  and  $y_t^1 = -2y_t^2$  from (3.9) and (3.10) into (6.5) we obtain,  $r_t^I(t, \sigma) = y_t^2 / 3\pi_{rr}^I < 0$ . \*\*\*

In Figure 2, the responses of the prices  $r^I$  and  $r^M$  to changes in the tariff  $t$  are shown by the lines ISB and MB respectively. From Proposition 1, ISB lies above MB ( $r^I$  exceeds  $r^M$ ) at all points other than at B where the tariff  $t^*$  is prohibitive. At  $t^*$ , exports  $y_1$  are zero and, from (4.3) and (4.4), both firm I and firm M supply the input at the independent monopoly price. At the origin where  $t = 0$ , firm I is shown as setting the foreclosure price  $r^P$ . Since  $r^P$  is increasing in  $t$  (see (3.12)), the line ISB has a positive slope up to the point S at which firm I starts supplying its rival with the intermediate product. The slope SB is then negative because  $r^I$  is decreasing in  $t$  in the region of vertical supply. In contrast, the price  $r^M$  for intermediates set by firm M is increasing in  $t$  over the entire range as illustrated by the positive slope of MB.

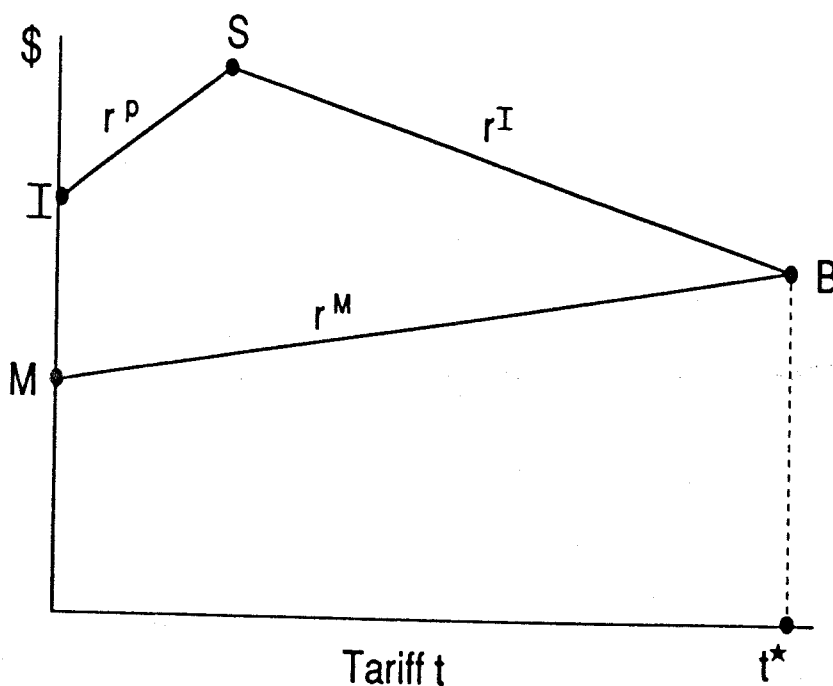


Figure 2

Considering the final product alone, the domestic country has an incentive to impose a profit-shifting import tariff on the basis of the Brander and Spencer (1984a) analysis. The tariff shifts profits to the domestic firm by giving it a

greater share of the market for the final product. When the intermediate product is supplied by the foreign vertically integrated firm, there is an additional domestic benefit from the improvement in the terms of trade on intermediate imports. As well as the usual consumer benefit, the reduction in domestic marginal cost from a lower import price for the input serves further to improve the domestic firm's competitive position (and its profits) in the market for the final product<sup>13</sup>.

### 7. Constant Marginal Cost of Domestic Production

We now consider the special case in which the domestic marginal cost of production of the input is constant at  $c_2$ . If this marginal cost is prohibitively high, our previous analysis applies. Domestic welfare is then increased by a small subsidy to intermediate imports so as to induce firm I to supply the input as in Section 5 and firm I's response in the region of vertical supply is as set out in Section 6. In the remainder of this Section we assume that entry by the domestic firm is profitable even if firm I forecloses.

If the domestic firm preferentially uses its own supplies when imported supplies cost the same, then imports of the intermediate product will be reduced to zero at  $r^p = c_2 - \sigma$ . If  $r$  is set even slightly below  $c_2 - \sigma$  then the domestic firm produces using only imported supplies. At this price, the domestic firm is just deterred from entering as a producer of the input. As Spencer and Jones (1989) point out, in the absence of government intervention, the foreign vertically integrated firm will always choose to supply the domestic rival. By setting  $r$  at the entry-detering value  $r^d$  just below  $r^p$ , say at  $r^d = r^p - \delta$  where  $\delta$  is small, firm I earns profit from the export of the input, but this action does not affect the domestic firm's marginal cost or firm I's profit from the export of the final product. An internal solution with  $r^i$  strictly below  $r^d$  is also possible.

The foreign vertically integrated firm sets the entry-detering price  $r^d = c_2 - \sigma - \delta$  if a small reduction in  $r$  below  $r^d$  reduces its profit<sup>14</sup>: if (from (3.5) and (4.3) at  $x_2 = 0$ ),

$$\pi_r^I(r^d, t, \sigma, s) = y_2 - (p - r^d - (t+s))y_r^2 \geq 0. \quad (7.1)$$

An internal equilibrium with  $r^I < r^d$  is profitable only if  $t+s$  is sufficiently large and positive to make condition (7.1) strictly negative. In other words, additional sales of intermediates above the level required just to deter entry occur only if a large import subsidy makes this market substantially more profitable or if the export market for the final product becomes much less important because of a large tariff  $t$ . At such an internal equilibrium,  $r^I$  satisfies our first order condition (4.3) with  $x_2 = 0$  and, again, our previous analysis of Section 6 applies. The possibility that firm I sets the price  $r^d$  is the only subcase not covered by our previous general analysis.

Firm M will also choose to set the entry-detering price  $r^d$ , if the domestic marginal cost  $c_2 - \sigma$  is below the unconstrained monopoly price<sup>15</sup>. At any price above  $r^d$ , firm M's sales would drop to zero, since the domestic firm would produce all its own supplies. As shown in Proposition 8, a small tariff on intermediate imports would then be fully absorbed by either firm I or firm M. Both foreign suppliers gain from continuing to prevent domestic production of the input.

**Proposition 8**

If firm I or firm M price their exports of intermediates at  $r^d$  so as just to deter domestic entry into the production of intermediates, then a small tariff on intermediate imports has no effect on the level of supply or on the price  $r^d$  paid by the domestic firm.

Proof: Since  $r^d = c_2 - \sigma - \delta$ , then a tariff (negative value of  $s$ ) has no effect on the

price  $r^d$ . It is profitable for firm I and firm M to continue to supply the domestic firm with the input, provided that the profit margin  $r^d + s - c_1$  earned on these sales is strictly positive. Since  $c_2 > c_1$ , this holds for a small negative value of  $s$ . \*\*\*

Proposition 8 implies that, at the entry-detering equilibrium, a tariff on intermediate imports is a perfect rent extracting device<sup>16</sup>. Also, since firm I and firm M set the same price and respond in the same way, vertical integration by the foreign supplier plays no role. This result is then very closely related to a Brander and Spencer (1981) result that an import tariff is a perfect rent extracting device when a foreign monopolist exporting a final product is trying to prevent domestic entry into the production of the final product. However, in this current application, the equilibrium is very fragile. If the marginal cost at which the input can be produced domestically is only slightly increasing, then an internal solution occurs in which the intermediate product is both imported and produced domestically. It then tends to be optimal to subsidize rather than to tax intermediate imports whether the equilibrium exhibits vertical foreclosure (see Proposition 3) or vertical supply (see Proposition 6).

A recent paper by Rodrik and Yoon (1989) assumes a constant marginal cost of domestic production, as in this section, but with a fixed cost of domestic entry as well. The entry-detering price then exceeds domestic marginal cost because the domestic firm must incur the fixed cost in order to enter. This fixed cost element implies that a tariff on the final product reduces the input price charged by the foreign supplier at the entry-detering equilibrium, whereas in our case, with no fixed costs, the price  $r^d = c_2 - \delta$  is unaffected by  $t$ .

A neglect of the possibility that domestic marginal cost is increasing rules out an important class of cases in which a key intermediate input is both

imported and produced domestically. In particular, in our computer industry example, semiconductor chips are both imported into the U.S. from Japan and produced within the U.S.. The case of increasing costs also reveals the importance of the role played by the vertical integration of the foreign supplier (as compared with a simple monopoly). Moreover, policy conclusions concerning the desirability of a tax, as opposed to a subsidy, on intermediate imports are substantially altered.

#### 8. Concluding Remarks

A foreign vertically integrated firm has an incentive to restrict the extent to which it supplies a higher cost domestic firm with an input when both firms compete in a Cournot market for the final product. The vertically integrated structure of the foreign supplier leads it to price the intermediate input above the level that would be set by a foreign monopoly exporting only intermediates, and, at the extreme, to engage in vertical foreclosure. In a domestic context, anti-trust action would be the commonly suggested remedy, but this policy tool is not normally available to domestic firms facing injury from a foreign firm.

In an international setting, a tariff applied to imports at the final product stage and, more directly, an import subsidy on the input itself can both be effective policy tools in inducing the vertically integrated firm to supply greater quantities of the input, even starting from a situation of full vertical foreclosure. Although subsidization of domestic production of the input tends to reduce the quantity supplied by the foreign firm, the domestic country benefits because the price paid for imported supplies also tends to fall.

In considering the policy implications of our results, it is useful to interpret the model more broadly to include the possibility that it is a foreign government rather than a single foreign vertically integrated firm that is



restricting exports of the intermediate product. This is legitimate since foreign national welfare is maximized by setting an export quota for intermediates that maximizes firm I's objective function: the total profit from the joint export of both the intermediate and final products. This interpretation broadens the class of industries in the exporting country to which our theory might apply<sup>17</sup>. The intermediate product could be produced by a vertically integrated oligopolistic industry, as in our semiconductor chip example, or by a competitive industry producing a natural resource product such as raw lumber, oil, or gas. By imposing export restrictions, the exporting country gains from the promotion of greater production and export of profitable final products as well as from the direct increase in revenues from the export of the manufactured component or raw material itself.

Given this broader context, our results indicate that all three domestic policies, a tariff on final good imports, a subsidy to domestic production of the input, and a subsidy to intermediate imports, tend to reduce the incentive for the foreign export quota to be set below the level required for simple maximization of monopoly rents from intermediate exports alone. If the domestic government sets a tariff on final product imports, rather than "retaliating", the foreign government may have an incentive to relax its export quota. If demand is linear, such relaxation is sufficient actually to reduce the price which need be paid for intermediate imports. In contrast, a simple maximization of rents from intermediate exports alone would generally lead the foreign government to raise the export price in response to the tariff.

The weight given to the policy implications of this analysis might reasonably depend on the robustness of the conclusions across different market structures. Jones and Spencer (1989) analyze government policy towards

vertically related markets, but in the context of a general equilibrium model in which both the intermediate and final products are produced by competitive industries. The gains from trade policy then arise from general equilibrium responses of wages and prices rather than profit shifting effects under imperfect competition. Despite the major differences between the two models, the analysis of the present paper and Jones and Spencer (1989) point to similarities in policy conclusions<sup>18</sup>. There is an incentive for a country exporting an intermediate product used as an input to foreign competitors in the final goods market to restrict its exports of intermediates even more tightly than suggested by simple monopoly pricing. Also, commercial policy on the part of the importing country may usefully be employed to lessen such export restrictions. Despite inherent ambiguities in general equilibrium analysis, in both contexts a tariff on final good imports can be a useful tool by which an importing country may obtain greater access to low cost foreign supplies of intermediates.

## APPENDIX A

Domestic welfare is assumed to be based on the additive utility function,  $W = u(Y) + z$  where  $u(Y)$  is utility from the consumption of  $Y$  and  $z$  is utility from the consumption of a numeraire good  $z$  ensuring that the marginal utility of income is equal to 1. The marginal product of labor in the production of  $z$  is assumed to be constant, fixing the wage at  $w$ . Both labor and a specific factor are required for the production of the input  $x_2$  so that the marginal cost of production of  $x_2$  increases as a consequence of a diminishing marginal product of labor. The domestic firm's profit,  $\pi^2$ , includes the return to this specific factor. Setting domestic income (including the tariff revenue less subsidy payments) equal to expenditure and substituting for  $z$  in  $W$ , we obtain the usual welfare function used in partial equilibrium analysis:

$$W = u(Y) - pY + \pi^2 + wL + ty_1 - \sigma x_2 - sx \quad (A1)$$

where  $L$  is the total supply of labor.

At a vertical supply equilibrium,  $x$  is positive and using  $u'(Y) = p$  and  $d\pi^2/ds = (y_2 p' y_r^1 - x)r_s$ ,

$$dW/ds = -(y_1 p' Y_r + y_2 p' y_r^2 + x)r_s - (x + s x_r r_s) . \quad (A2)$$

We now prove Propositions 3 and 6 of the text.

**Proposition 3:** If firm I chooses vertical foreclosure at  $t=\sigma=s=0$ , then domestic welfare is increased by a sufficiently large subsidy to intermediate imports to induce firm I to supply the input to the domestic firm.

**Proof:** Let  $s^F$  represent the critical value of  $s$  at which firm I just chooses foreclosure. From (4.3) at  $x = 0$ , and using (3.5) to substitute for  $y_1 p'$ ,  $s^F$  satisfies,

$$\pi_r^I(r^P, 0, 0, s^F) = s^F x_r + (r^P - p)y_r^2 - (r^P - c_1)x_r^2 = 0 \quad (A3)$$

Rearranging (A3) using  $r^p - p = y_2 p'$  from (3.6), we obtain,

$$s^F = [-y_2 p' y_r^2 + (r^p - c_1) x_r^2] / x_r. \quad (A4)$$

Since  $x=0$ , the subsidy  $s$  has no effect on welfare if  $s \leq s^F$ . A small increase in  $s$  above  $s^F$  induces vertical supply and, at  $s^F$ , from (A2), (A4),  $x=0$  and  $r_s^I < 0$  (see Proposition 5),

$$dW/ds = -[y_1 p' Y_r + (r^p - c_1) x_r^2] r_s > 0. \quad (A5)$$

Given vertical foreclosure at  $s=0$ ,  $s^F$  is positive and (A5) shows that a small subsidy above this level increases domestic welfare.

\*\*\*

**Proposition 6:** (Assume  $p''(Y)=0$  and  $x_{rr}^2=0$ ). If there is vertical supply at  $t=\sigma=s=0$ , then a small import subsidy on intermediates supplied by either firm I or firm M increases domestic welfare.

**Proof:** From Proposition 5,  $r_s^M = -x_r / \pi_{rr}^I = -1/2$  if demand and supply are linear. Substituting for  $r_s^I$  in (A2), we obtain,

$$dW/ds = [y_1 p' Y_r + y_2 p' y_r^2 - x + s x_r] / 2 \quad (A6)$$

Substituting  $p' Y_r = 1/3$  and  $p' y_r^2 = 2/3$  from (3.10) into (A6), we have  $dW/ds = (y_1 + 2y_2 - 3x + 3s x_r) / 2 > 0$  at  $s=t=0$ . This follows since firm 2's output  $y_2$  is never less than its imports  $x$  and, from  $c_1 < r$  and  $t = 0$ , firm I's exports  $y_1$  exceed  $y_2$ .

Similarly for firm I, substituting  $r_s^I = -x_r / (2x_r - p' Y_r y_r^2)$  into (A2),

$$dW/ds = [(y_1 p' Y_r + y_2 p' y_r^2 - x + s x_r) x_r + x p' Y_r y_r^2] / (2x_r - p' Y_r y_r^2) \quad (A7)$$

which is positive at  $s=t=0$  since (A6) is positive under these conditions.\*\*\*

## FOOTNOTES

\* This paper is a revised version of an earlier 1988 manuscript entitled "Protectionist Policies in Vertically Related International Markets". In this revision we have taken the opportunity, in Section 7, to comment on the recent paper by Rodrik and Yoon (1989), which addresses some of the same issues. Barbara Spencer gratefully acknowledges financial support from SSHRC grant no. 410-88-0074 and from the Centre for International Business Studies at U.B.C..

1. Two notable recent papers in which vertical integration leads to a refusal to supply a rival are Ordover, Saloner and Salop (1988) and Salinger (1988). In Quirmbach (1986) vertical supply occurs when the downstream industry is perfectly contestable and the monopolist's downstream subsidiary faces diminishing returns. In Katz (1987), buyers of an intermediate input have the ability to integrate backward into the supply of an input and this affects the price charged for the input by an upstream supplier. Another relevant paper is Salop and Scheffman (1983), which develops the idea that a dominant firm may gain by raising the costs of its rival through union contracts and other means that also serve to raise its own costs.

2. The assumption of fixed proportions technology fits with our semiconductor chip example. If inputs are substitutable, an increase in the price of the intermediate product would cause the rival firm to substitute away from the higher priced input making price increases less profitable. However, the ability of the rival firm to produce its own supplies of the intermediate product plays a similar role under fixed proportions technology, so that introducing substitutability between inputs should not change the general nature of the results.

3. These conditions require that own marginal profit is decreasing in the other firm's output:  $\pi_{12}^1 = p' + y_1 p'' < 0$  and  $\pi_{21}^2 = p' + y_2 p'' < 0$ . This is sufficient to guarantee that the second order conditions for profit maximization hold ( $\pi_{11}^1 < 0$  and  $\pi_{22}^2 < 0$ ) and that the equilibrium exists and is unique ( $H = \pi_{11}^1 \pi_{22}^2 - \pi_{12}^1 \pi_{21}^2 > 0$ ). Reaction functions in output space are negatively sloped.

4. There is no discontinuity in  $x(r, t, \sigma)$  at  $r = r^p$ . The implicit function theorem can be applied to the first order conditions (3.5) and (3.6) to show the continuity of  $y^1(r, t)$  and  $y^2(r, t)$  and their partial derivatives for  $r \leq r^p$ . If domestic production of  $x_2$  is prohibitively expensive, then firm 2's Cournot equilibrium level of  $y_2$  as well as its demand for  $x$  reduce smoothly to zero as  $r$  increases to  $r^p$ .

5. Firm I chooses  $x \geq 0$  or equivalently  $r \leq r^p$  to maximize (4.1). We assume that  $\pi^I$  is strictly concave over the domain  $r \leq r^p$  ensuring that  $\pi^I$  achieves a global maximum. With linear demand and supply, ( $p''(Y) = 0$  and  $x_{rr}^2 = 0$ ), the second order condition holds ( $\pi_{rr}^I = (2-p'Y_r)y_r^2 - 2x_r^2 < 0$ ) except at  $r = c_2 - \sigma$ . Although  $\pi_r^I$  is continuous it is not differentiable at  $r = c_2 - \sigma$  because  $x_2 = 0$  if  $r < c_2 - \sigma$  and  $x_2(r) > 0$  otherwise. However  $\pi^I$  remains strictly concave since  $x_r^2 = 0$  for  $r \leq c_2 - \sigma$  and  $x_r^2 < 0$  for  $r \geq c_2 - \sigma$ .

6. The firm producing the final good in country 1 pays no monopoly markup on the intermediate input under either scenario. An alternative formulation would be to assume that firm M also supplies the foreign independent producer of the final good with the intermediate input so that it pays a monopoly markup in the benchmark case. This would be appropriate if, as in most of the literature concerned with vertical integration, the aim is to determine the effect of vertical integration per se in a domestic context in which all firms face identical costs prior to vertical integration. However, our purpose is to

determine the effect of joint control of exports of the two vertically related products relative to independent supply to the export market. This comparison is made most directly by maintaining the price paid by the foreign firm for the intermediate input constant across the two cases.

7. Since  $r^p(t, \sigma)$  and  $y_1(r^p, t)$  are independent of  $s$ , we have, from (4.3) with  $x = 0$ ,  $d\pi_r^I(r^p, t, \sigma, s)/ds = x_r < 0$ . Condition (4.2) for vertical supply will be satisfied if  $s$  is sufficiently large and positive to make  $\pi_r^I(r^p, t, \sigma, s) < 0$ .

8. To show this, it is convenient to assume that the domestic firm's marginal cost of production of  $x_2$  is linear, so as to abstract from second order effects of  $\sigma$  on the slope of marginal cost. The subsidy  $\sigma$  then simply serves to shift down the marginal cost curve and affects  $\pi_r^I$  only through its effect on  $r^p$ . From (4.3) at  $r = r^p$  (with  $x = 0$ ),  $d\pi_r^I/d\sigma = \pi_{rr}^I r_\sigma^p > 0$ , indicating that an increase in  $\sigma$  reduces the incentive for vertical supply.

9. Allowing for general demand and supply functions,  $r_\sigma^M = (x_\sigma^2 + (r - c_1)x_{r\sigma}^2)/\pi_{rr}^M$  and  $r_\sigma^I = (x_\sigma^2 + (r - c_1)x_{r\sigma}^2)/\pi_{rr}^I$  are negative provided  $x_{r\sigma}^2$  is not too large and negative. From  $x_r^2(r + \sigma) = 1/C_{xx}^2$ ,  $x_{r\sigma}^2 = x_{rr}^2 = x_r^2/C_{xxx}^2$  is (weakly) positive if the rate of increase in marginal cost is increasing or constant.

10. From (3.8),  $dx/d\sigma = x_r dr/d\sigma - x_\sigma^2$ . From (6.1), with some manipulation we obtain,  $dx^I/d\sigma = -[x_\sigma^2 y_r^2 (1 - p' Y_r) - x_\sigma^2 x_r^2]/\pi_{rr}^I < 0$  and  $dx^M/d\sigma = -x_\sigma^2/2 < 0$ .

11. Brander and Spencer (1984b) show that, under certain demand conditions, it may be optimal to subsidize imports supplied by a foreign monopolist. Jones (1987) sets out a general condition related to the elasticity of demand which determines whether a subsidy rather than a tariff is optimal.

12. Although some restrictions on both  $p''(Y)$  and  $p'''(Y)$  are required to ensure that a monopolist responds to an increase in demand by increasing price and output, this result holds under most demand conditions.

13. However, to the extent that firm I's exports of the final product  $y_1$  are reduced by a lowering of the price  $r^I$  charged for intermediates, the tariff  $t$  becomes less effective as a means of raising tariff revenue. Although the gains from a small tariff are increased by the joint supply of the two products, the increased loss in tariff revenue means that the optimal tariff level may fall.

14. Firm I chooses  $r$  to maximize  $\pi^I$  subject to  $r \leq r^c$ . At the maximum,  $r$  satisfies the first order condition,  $\pi_r^I - \mu = 0$ , where the Lagrange multiplier  $\mu$  is strictly positive if the solution is at  $r^c$ .

15. Firm M chooses  $r$  to maximize  $\pi^M$  subject to  $r^d - r \geq 0$ . At the optimum,  $r^M$  satisfies  $\pi_r^M - \mu = y_2 + (r^M + s - c_1)y_r^2 - \mu = 0$ . If the constraint is binding ( $\mu > 0$ ) then  $r^M = r^d$ .

16. This is also the case for a subsidy  $\sigma$  to domestic production. Since  $r^d = c_2 - \sigma - \delta$ , an increase in  $\sigma$  directly reduces  $r^d$  by the same amount. However, since the subsidy is never paid, there may be some question as to its credibility.

17. The Cournot market for the final product could also be interpreted as arising from the actions of marketing boards in both countries (see Krishna and Thursby (1988)).

18. In Jones and Spencer (1989), we reference an earlier version of this paper and provide a discussion of the relationship of some of our results with similar results arising in the general equilibrium purely competitive framework. Particular attention is given to our Proposition 7 that under linear demand, a vertically integrated supplier responds to a tariff on the final product by reducing the input price charged its rival.



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