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Trade Liberalization and Strategic Outsourcing

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Abstract

This paper develops a model of strategic outsourcing. With trade liberalization in the intermediate-product market, a domestic firm may choose to purchase a key intermediate good from a more efficient foreign producer, who also competes with the domestic firm for a final good. This has a strategic effect on competition. Unlike the outsourcing motivated by cost saving, the strategic outsourcing has a collusive effect that could raise the prices of both intermediate and final goods. Trade liberalization in the intermediate-good market could have a very different effect compared with trade liberalization in the final-good market.

Key Words: Outsourcing; Vertical oligopolies; Collusive effect

JEL classification: F12; F13

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1. INTRODUCTION

One of the most significant effects of trade liberalization on patterns of production and trade during the last decade is the phenomenon of international 'outsourcing' and/or 'fragmentation'. International outsourcing and fragmentation have been well documented, and their effects on production and input markets are the subject of many recent empirical studies.[1] They are often viewed as a way for firms to look for cheaper suppliers to cope with increasing international competition. It was quite recently, however, that the development of rigorous theories in this area began. Those theories are broadly based on two approaches. The first approach, which is adopted in most studies in the literature, focuses on perfectly or monopolistically competitive market structure, especially regarding the intermediate product market (e.g., Jones, 2000; Jones and Kierzkowski, 2001).[2] The second approach, which has its origin in the industrial organization literature, focuses on the issues associated with transaction costs and incomplete contracts (e.g., McLaren, 2000). Under these theories the effects of outsourcing are pro-competitive and economically efficient, in the sense that they result in lower prices for both intermediate and final products.

In this paper, we consider an unnoticed feature of outsourcing, namely, that outsourcing firms sometimes purchase a key intermediate input from more efficient suppliers that are also their rivals in the final goods market. International outsourcing of this nature is common in many industries, such as computer and automobile industries. We argue that in these situations the usual cost-saving motive for outsourcing could be accompanied by a strategic motive, and that the *strategic outsourcing* in response to trade liberalization in intermediate goods can result in *higher* prices for both intermediate and final goods.

We consider a model where two firms, one domestic and one foreign, produce a differentiated product using a homogenous intermediate input and compete in the domestic market. The foreign firm has a lower (marginal) cost in producing the intermediate input and thus

[1] See Feenstra and Hanson (1996a, 1996b), Hanson (1996), Slaughter (1995), and many others.

[2] Arndt and Kierzkowski (2001), and Cheng and Kierzkowski (2001) are recent two volumes on fragmentations. Also, among others, Harris (2001), and Long, Riezman and Soubeyran (2001) model services as intermediate inputs to investigate fragmentation.

always stays integrated. The domestic firm, however, can either produce the intermediate input itself at a higher cost or purchase the intermediate input from the integrated foreign firm. Recognizing that they may compete in the final-product market, the domestic firm has an extra incentive to purchase its input from the foreign firm because this will weaken the incentive of the latter to compete in the final-good market. In a two-stage game where the choice of the supplier of the intermediate input is determined in the first stage and the two firms then engage in Bertrand competition in the final-product market, we establish the following three main results.

First, trade liberalization for the intermediate input would lead to strategic outsourcing. But when the strategic outsourcing occurs, the domestic firm may actually pay more (including the tariff) for the intermediate input than it would cost to produce the good domestically, resulting in higher prices for the final product. Second, in contrast to the common view in the current literature, we show that in the outsourcing equilibrium, further trade liberalization in the intermediate input could raise the prices of both the intermediate and final products. Third, the effects on the intermediate and final products of trade liberalization in the final-good market are very different from those in the intermediate-good market, depending on the demand characteristics of the final goods. For instance, when trade liberalization in the final good reduces consumer prices, trade liberalization in the intermediate good could have an opposite effect.

There is considerable evidence for the kind of international outsourcing that we discuss in this paper.[3] For example, it is well known that Taiwanese PC producers (e.g., Acer) supply mother boards, PCBs, and other inputs to other foreign PC producers. Similar practices are often observed in automotive industries. Traditionally, the production of engines has been kept in-house and engines are only used in the manufacturer's *own* vehicles. This practice is not difficult to understand given that engines are the most important component in automobiles. However, according to *Automotive Industries* (July 1999), Mitsubishi is

[3]Also, the intermediate good does not need to be a "real" input. A good example is original equipment manufacturing (OEM). That is, a firm outsources a product to other firms and sells it under its own brand. OEM is widely observed in a number of manufactured products such as electric appliances.

poised to sign a series of deals with Fiat Auto and it is likely that Mitsubishi's GDI (gasoline direct injection) engines would power several new Fiat models. More interestingly, Honda is famous for its unique DCR (direction of crankshaft rotation) engines and their superior quality but the company has decided to abandon DCR and will incorporate its technology to produce more conventional GDI engines that are suitable for installation in other carmakers' models. "From now on we will be able to sell our engines to other carmakers", said a Chief Executive Hiroyuki Yoshino of Honda Motor Co. (*Automotive News Europe, 25* October 1999).

To our knowledge, there are no studies in the literature that explore the strategic incentives of international outsourcing and its potential collusive effects associated with trade liberalization. Using the 'transaction cost' and 'incomplete contract' approach, McLaren (2000) and Grossman and Helpman (2001) are the recent studies that focus on trade liberalization and vertical structure under imperfect competition.[4] In McLaren, for instance, trade liberalization lowers transaction costs and makes it easier for an input supplier to find an attractive buyer abroad, which strengthens its bargaining power *ex post* and thus makes an arm's-length arrangement more attractive. Trade liberalization therefore unambiguously enhances efficiency because of thickening of the market.

Zhao (2001) also considers outsourcing and the vertical (and horizontal) structure of a multinational firm. The paper, however, focuses on the effects of domestic unionization - in particular, how unionization in vertically related markets can make firms become both vertically and horizontally related multinationals.

Our analysis is also related to studies that deal with some strategic aspects in the vertically related markets.[5] In particular, Spencer and Raubitschek (1996) show that domestic producers faced with monopoly pricing by a foreign supplier of a key input, may choose to form a domestic joint venture to produce part of the input at an even higher cost than the monopoly price. The joint venture provides a commitment for domestic firms to buy part of

[4] Raff and Schmitt (2000) investigate how trade liberalization would affect the type of retailling contracts.

[5] See Spencer and Jones (1991, 1992), Ishikawa and Lee (1997), Krishna and Morgan (1998), Ishikawa and Spencer (1999), and Ishikawa (1999), among many others.

the input domestically (at a higher cost), which reduces the demand for imported supplies. The purpose of their paper is to show that the reduction in demand may sufficiently reduce the price charged by the foreign monopolist to overcome the domestic cost disadvantage. The collusive effect of the kind we investigate is not captured in their study.[6]

The rest of the paper is organized as follows. Section 2 characterizes the equilibrium under non-outsourcing and under outsourcing. Section 3 analyzes the effects of trade liberalization on the equilibrium outcome (outsourcing versus non-outsourcing) and on the prices of the intermediate and final products. Section 4 discusses some alternative assumptions and the robustness of our results. Section 5 provides some concluding remarks.

2. THE MODEL

There are two firms: firm D is located in the *domestic* country and firm F is located in the *foreign* country. These firms produce a differentiated final product, Y, using a homogenous intermediate good, X. There is potential trade in both goods and two firms compete in prices in the *domestic* market only.[7] The (domestic) demand for the two firms' products is $q_i(p_i, p_j)$, $i, j = D, F$, where p_i is the (consumer) price of the final product produced by firm i. The marginal cost of producing the intermediate good X is a constant, m_D for firm D and m_F for firm F, where $0 \leq m_F < m_D$. Thus the foreign firm is more efficient in producing the intermediate good. We assume that only firm F produces the intermediate good X in the foreign country. Other costs of producing Y are normalized to zero, and to produce one unit of good Y requires one unit of the intermediate good X.

[6] In Chen (2001) it is pointed out that the analysis of competition in vertically related markets needs to take into account the effects of multimarket contacts. Chen uses this idea to develop a theory of vertical mergers. While the intuition in our analysis is related to that in Chen, our paper addresses very differnt issues: we are interested in the incentives for international outsourcing and the effects of trade liberalization in the presence of strategic outsourcing.

[7] The foreign firm can also serve its own domestic market, but this would matter little to our analysis as long as firm D does not compete there. Alternatively, one could think that two firms compete in the integrated world final-good market if there is no tariff on the final good (i.e., $t_y = 0$). In this case, our analysis and results in 3.2 need no modification at all.

In the domestic country, there are specific tariffs on imports of both goods: t_y for the final good Y and t_x for the intermediate good X. We do not introduce active domestic or foreign governments into the model since optimal trade policy is beyond the scope of the present paper. Our main interests are the effects of trade liberalization (which is represented by a reduction in t_x or t_y) on the equilibrium decision about outsourcing and on the prices of intermediate and final products.

The game proceeds as follows. In the first stage, with given t_x and t_y, firm F commits to a (producer) price, w, for the intermediate good (if it sells X); and firm D decides whether to contract to buy the intermediate good from firm F or to have it produced internally.[8] In the second stage, firm D and firm F compete in price (Bertrand) for the differentiated final good Y in the domestic market.[9] We assume that prices are strategic complements in the usual sense. We also assume that outsourcing would be an equilibrium if no firm is worse off (since there is no transfer payment) and at least one firm better off under outsourcing.

The subgame perfect equilibrium of the model is solved by backward induction. We first characterize Nash equilibrium in the subgame where firm D chooses non-outsourcing. We then characterize the equilibrium in the subgame where firm D chooses outsourcing, that is, to purchase the intermediate good from firm F. The equilibrium outsourcing decision, as well as the equilibrium price for X (if firm D purchases from firm F) is then determined.

Equilibrium under non-outsourcing

If firm D produces the intermediate good by itself, the profit functions for firms D and F are

$$\pi_D = (p_D - m_D)q_D(p_D, p_F) \tag{1}$$

$$\pi_F = [p_F - (m_F + t_y)]q_F(p_F, p_D) \tag{2}$$

[8] Thus, we are assuming that firm D can commit to purchase all input from firm F. The implications of realxing this assumption is discussed in Section 4.

[9] We will briefly discuss quantity competition in Section 4.

The equilibrium prices, denoted as $p_D(m_D, t_y)$ and $p_F(m_D, t_y)$, satisfy the following first-order conditions:[10]

$$q_D(p_D(m_D,t_y), p_F(m_D,t_y)) + [p_D(m_D,t_y) - m_D]\frac{\partial q_D(p_D,p_F)}{\partial p_D} = 0 \tag{3}$$

$$q_F(p_F(m_D,t_y), p_D(m_D,t_y)) + [p_F(m_D,t_y) - (m_F + t_y)]\frac{\partial q_F(p_F,p_D)}{\partial p_F} = 0 \tag{4}$$

We assume that the stability condition is satisfied and there exists a unique equilibrium for relevant parameter values of m_D and t_y. The equilibrium profits of firms D and F are denoted by $\pi_D(m_D, t_y)$ and $\pi_F(m_D, t_y)$. Notice that $\pi_D(m_{D,}t_y)$ will be firm $D's$ fall-back level of profit when it decides whether or not to go outsourcing.

Equilibrium under outsourcing

If firm D contracts to buy the intermediate good X from firm F at price w (and pays the import tariff t_x), the profit functions for firms D and F are

$$\widetilde{\pi}_D = (p_D - w - t_x)q_D(p_D, p_F) \tag{5}$$

$$\widetilde{\pi}_F = [p_F - (m_F + t_y)]q_F(p_F, p_D) + (w - m_F)\, q_D(p_D, p_F)\,. \tag{6}$$

The equilibrium prices, denoted as $\tilde{p}_D(w, t_x, t_y)$ and $\tilde{p}_D(w, t_x, t_y)$, satisfy the following first-order conditions:[11]

$$q_D(\tilde{p}_D(w,t_x,t_y), \tilde{p}_F(w,t_x,t_y)) + [\tilde{p}_D(w,t_x,t_y) - (w + t_x)]\frac{\partial q_D(\tilde{p}_D,\tilde{p}_F)}{\partial p_D} = 0 \tag{7}$$

$$q_F(\tilde{p}_F(w,t_x,t_y), \tilde{p}_D(w,t_x,t_y)) + [\tilde{p}_F(w,t_x,t_y) - (m_F + t_y)]\frac{\partial q_F(\tilde{p}_F,\tilde{p}_D)}{\partial p_F} + (w - m_F)\frac{\partial q_D(\tilde{p}_D,\tilde{p}_F)}{\partial p_F} = 0 \tag{8}$$

[10] Throughout the paper, we shall treat m_F as exogeneously fixed and shall thus not include it as an argument in any functional expressions.

[11] As usual in the literature, we also assume that prices are strategic complements, the stablility condition is satisfied, and the model has a unique equilibrium for relevant parameter values (e.g., see Chen, 2001).

We denote the equilibrium profits by $\tilde{\pi}_D(w, t_x, t_y)$ and $\tilde{\pi}_F(w, t_x, t_y)$. Clearly, in order for outsourcing to occur in equilibrium, we must have $\tilde{\pi}_i(w, t_x, t_y) \geq \pi_i(m_D, t_y)$, $i = D, F$.

Notice that $w + t_x$ is the effective marginal cost for firm D, and t_y is part of the marginal cost of firm F. From standard oligopoly theory, for any w, t_x, and t_y that yield positive outputs for both firms, an increase in w (or in t_x or in t_y) would increase the prices for the final goods. Intuitively, given the other firm's price, a firm's optimal price increases in its marginal cost. Since prices are strategic complements, the incentive to raise prices for one firm leads to higher prices for both firms.[12] That is, for $i = D, F$,

$$\frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial w} > 0 \text{ and } \frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial t_j} > 0 \text{ for } j = x, y. \tag{9}$$

Furthermore, since w and t_x enter equation (7) symmetrically as part of the effective marginal cost for firm D but w also enters equation (8), an increase in w will increase the price more than an increase in t_x.[13] Totally differentiating (7) and (8), it is straightforward to show that

$$0 < \frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial t_x} < \frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial w}. \tag{9'}$$

Now, using the envelope theorem, we have

$$\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial w} = -q_D(\widetilde{p}_D, \widetilde{p}_F) + (\widetilde{p}_D - w - t_x)\frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial p_F}\frac{\partial \widetilde{p}_F(w, t_x, t_y)}{\partial w},$$

where the first term is negative and the second term is positive. An increase in firm $D's$ input cost, w, has two opposite effects on firm $D's$ equilibrium profits. The direct effect is that each unit sold by firm D costs more, which reduces firm $D's$ profit. The indirect effect is that a higher w induces a higher p_F, which increases the demand for firm D and thus

[12] In terms of reaction curves, an increase in w or in t_x (or in t_y) shifts firm $D's$ (or $F's$) upward-slopping reaction curve to the right (or up), causing an increase in the equilibrium prices.

[13] That is, an increase in w increases the per-unit profit of firm F from selling the input to firm D. For any price of firm D, firm F will then have more incentive to raise its price for the final product. An increase in w thus has a stronger effect raising prices for firms D and F than an increase in t_x.

increases firm $D's$ profit. Using (7), we further obtain

$$\begin{aligned}\frac{\partial \tilde{\pi}_D(w,t_x,t_y)}{\partial w} &= (\widetilde{p}_D - w - t_x)\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_D} + (\widetilde{p}_D - w - t_x)\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_F}\frac{\partial \widetilde{p}_F(w,t_x,t_y)}{\partial w} \\ &= (\widetilde{p}_D - w - t_x)[\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_D} + \frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_F}\frac{\partial \widetilde{p}_F(w,t_x,t_y)}{\partial w}],\end{aligned}$$

which would be negative if $|\partial q_D(\widetilde{p}_D,\widetilde{p}_F)/\partial p_F|$ is small relative to $|\partial q_D(\widetilde{p}_D,\widetilde{p}_F)/\partial p_D|$, i.e., the demand for firm D responds much more to its own price change than to the price change of F.[14]

Following the typical approach in the literature (e.g., Chen, 2001) and without going into the technical details that are not essential for our analysis, we shall assume that the direct effect dominates the indirect effect. Thus, firm D's profit decreases in its costs (either w or t_x):

$$\frac{\partial \tilde{\pi}_D(w,t_x,t_y)}{\partial w} < 0 \text{ and } \frac{\partial \tilde{\pi}_D(w,t_x,t_y)}{\partial t_x} < 0. \tag{10}$$

Similarly, using (6) and the envelope theorem, we have

$$\begin{aligned}\frac{\partial \tilde{\pi}_F(w,t_x,t_y)}{\partial w} &= [\widetilde{p}_F - (m_F + t_y)]\frac{\partial q_F(\widetilde{p}_F,\widetilde{p}_D)}{\partial p_D}\frac{\partial \widetilde{p}_D(w,t_x,t_y)}{\partial w} \\ &\quad + (w - m_F)\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_D}\frac{\partial \widetilde{p}_D(w,t_x,t_y)}{\partial w} + q_D(\widetilde{p}_D,\widetilde{p}_F).\end{aligned}$$

Notice that an increase in w means a higher price but a lower quantity sold for the intermediate good (the third and second terms, respectively), which is standard. Due to the multimarket contact, however, we now have the first term. This term is also positive since a rise in w would raise $\widetilde{p}_D$, which benefits firm F in the final-good market. We can also write that

$$\begin{aligned}&\frac{\partial \tilde{\pi}_F(w,t_x,t_y)}{\partial w} \\ &= \{[\widetilde{p}_F - (m_F + t_y)]\frac{\partial q_F(\widetilde{p}_F,\widetilde{p}_D)}{\partial p_D} + (w - m_F)\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial p_D}\}\frac{\partial \widetilde{p}_D(w,t_x,t_y)}{\partial w} + q_D(\widetilde{p}_D,\widetilde{p}_F),\end{aligned}$$

[14] It can be verified that $\partial \widetilde{p}_F(w,t_x,t_y)/\partial w$ tends to be small in these situations and is often less than 1. If $\partial \widetilde{p}_F(w,t_x,t_y)/\partial w < 1$, we would have $\partial \tilde{\pi}_D(w,t_x,t_y)/\partial w < 0$ if $|\partial q_D(\widetilde{p}_D,\widetilde{p}_F)/\partial p_F| < |\partial q_D(\widetilde{p}_D,\widetilde{p}_F)/\partial p_D|$.

which is positive if the difference between w and m_F is not too large. Thus, for the relevant range of w in our analysis,[15] we assume:

$$\frac{\partial \tilde{\pi}_F(w, t_x, t_y)}{\partial w} > 0, \tag{11}$$

or firm $F's$ equilibrium profit increases in w when it sells the input to firm D. Conditions (10) and (11), which are similar to the familiar assumptions made in the literature that a firm's equilibrium profit decreases in its own input costs and increases in its rival's input costs, are generally satisfied under plausible demand conditions (e.g., Chen, 2001). In the appendix we provide an example of linear demands where both conditions (10) and (11) hold together with other assumptions of the model.

As mentioned before, outsourcing would be an equilibrium if no firm is worse off and at least one firm has higher profit under outsourcing. This means that given the game specified above, in any equilibrium that involves firm $D's$ outsourcing from firm F, firm F will optimally choose its w (in stage 1) such that firm D's profit under outsourcing is the same as if it produces the input internally.[16] We therefore have:

Lemma 1 *The equilibrium price of the intermediate good, denoted as* $w(t_x, t_y)$, *satisfies* $\tilde{\pi}_D(w(t_x, t_y), t_x, t_y) = \pi_D(m_D, t_y)$ *and* $\tilde{\pi}_F(w(t_x, t_y), t_x, t_y) > \pi_F(m_D, t_y)$.

Furthermore, notice that the first-order conditions in equations (7) and (8) would be the same as those in equations (3) and (4) when both $w = m_F$ and $w + t_x = m_D$ hold. This means that $\tilde{p}_i(m_F, m_D - m_F, t_y) = p_i(m_D, t_y)$ and $\tilde{\pi}_i(m_F, m_D - m_F, t_y) = \pi_i(m_D, t_y)$, $i = D, F$. This observation is important for establishing the next result.

Lemma 2 *(i) In equilibrium* $w(t_x, t_y) > m_F$ *holds; (ii) when* $w > m_F$ *and* $t_x = m_D - w$, *we have* $\tilde{p}_i(w, m_D - w, t_y) > p_i(m_D, t_y)$, $i = D, F$.

[15] Since an increase in w reduces firm $D's$ profit, firm D may not want to purchase from firm F if w becomes too high. This limits how high firm F may be able to set its w.

[16] Obviously, $w \geq m_F$, since otherwise firm F would be better off not selling to firm D. We have assumed that firm F makes the offer of w that firm D can chooe either accept or reject. If firm D can bargain with firm F on the price for the intermediate good, our results would be essentially the same as long as firm $D's$ bargaining power is not too strong. See the discussion in Section 4 .

Proof: (**i**) Suppose to the contrary that $w(t_x, t_y) = m_F$. Then, since $\tilde{\pi}_D(w(t_x, t_y), t_x, t_y) = \pi_D(m_D, t_y)$ from Lemma 1, based on the discussion prior to Lemma 2 and (10) we would have $t_x = m_D - m_F$, and hence $\tilde{\pi}_F(w(t_x, t_y), t_x, t_y) = \tilde{\pi}_F(m_F, m_D - m_F, t_y) = \pi_F(m_D, t_y)$. This is a contradiction since we know that $\tilde{\pi}_F(w(t_x, t_y), t_x, t_y) > \pi_F(m_D, t_y)$ from Lemma 1. Thus $w(t_x, t_y) > m_F$. (**ii**) Notice first that when $t_x = m_D - w$, $w + t_x = m_D$. Compare the two first-order conditions in (7) and (8) under w and $t_x = m_D - w$ with those in (3) and (4). With $(w - m_F) > 0$, we must have $\tilde{p}_i(w, m_D - w, t_y) > p_i(m_D, t_y)$, since $\partial q_D/\partial p_F > 0$ and prices are strategic complements. ■

The intuition for part (ii) is as follows. Suppose firm F's best response function is $\partial\pi_F(p_F, p_D)/\partial p_F = 0$ when firm F does not supply firm D. It becomes $\partial\pi_F(p_F, p_D)/\partial p_F + (w - m_F)\partial q_D/\partial p_F = 0$ when firm F supplies firm D. Since $(w - m_F)\partial q_D/\partial p_F > 0$, it shifts up firm F's reaction function, resulting in higher prices.

Now we are ready to derive the next lemma.

Lemma 3 *When $w + t_x = m_D$ and $t_x < m_D - m_F$, we have $\tilde{\pi}_i(w, m_D - w, t_y) > \pi_i(m_D, t_y), i = D, F$.*

Proof: Since $w = m_D - t_x > m_F$, from Lemma 2 we have $\tilde{p}_i(w, m_D - w, t_y) > p_i(m_D, t_y)$. Now,

$$\begin{aligned}
\widetilde{\pi}_D(w, m_D - w, t_y) &= [\tilde{p}_D(w, m_D - w, t_y) - m_D]q_D(\tilde{p}_D(w, m_D - w, t_y), \tilde{p}_F(w, m_D - w, t_y)) \\
&\geq [p_D(m_D, t_y) - m_D]q_D(p_D(m_D, t_y), \tilde{p}_F(w, m_D - w, t_y)) \\
&> [p_D(m_D, t_y) - m_D]q_D(p_D(m_D, t_y), p_F(m_D, t_y)) \\
&= \pi_D(m_D, t_y),
\end{aligned}$$

where the first inequality is due to revealed preference and the second inequality is due to $p_F(m_D, t_y) < \tilde{p}_F(w, m_D - w, t_y))$. Similarly, it is also straightforward to show that $\widetilde{\pi}_F(w, m_D - w, t_y) > \pi_F(m_D, t_y)$. ■

The intuition for $\widetilde{\pi}_D(w, m_D - w, t_y) > \pi_F(m_D, t_y)$ is as follows. When firm D contracts to purchase from firm F at some price $w > m_F$, firm F will make profit in selling the intermediate good. Since firm D will purchase less from F if F reduces its final-good price, firm F becomes less willing to cut that price. Therefore, although firm D's input cost is $w + t_x = m_D$, the same as if it produces the input internally, it has a higher equilibrium profit due to the strategic effect on the pricing incentive of firm F for the final good. Now it is also not difficult to understand that $\widetilde{\pi}_F(w, m_D - w, t_y) > \pi_F(m_D, t_y)$ because, in addition to the strategic effect in the final-product market, firm F also makes profits from selling the intermediate good at $w > m_F$.

3. THE EFFECTS OF TRADE LIBERALIZATION

3.1 Trade liberalization in the intermediate good

Now we solve for the equilibrium decision in stage 1 and show how trade liberalization might affect the subgame perfect equilibrium (i.e., outsourcing or non-outsourcing). Although we only discuss import tariffs in this model, we interpret a decrease in their level more broadly as a reduction in trade barriers and/or an increase in the degree of globalization (i.e., reduction in trade costs in general). In this subsection, we focus on the effects of a reduction in the import tariff, t_x, on the intermediate good. We first find that the level of t_x will determine the nature of the equilibrium, as characterized by the next proposition.

Proposition 1 *There is equilibrium outsourcing if and only if* $t_x < m_D - m_F$.

Proof: We first show that there is equilibrium outsourcing if $t_x < m_D - m_F$. Suppose to the contrary that $t_x < m_D - m_F$ but there is no outsourcing. Then, firm F can offer $\hat{w} = m_D - t_x > m_F$. With firm $D's$ purchase of the input from F at $\hat{w}$, the profits of both firm D and firm F will be higher than no outsourcing according to Lemma 3. This produces a contradiction.

We next show that $t_x < m_D - m_F$ is also necessary for equilibrium outsourcing to occur. Suppose that $t_x \geq m_D - m_F$ but there is outsourcing. Notice that $w(t_x) > m_F$ from Lemma 2.[17] But since $\tilde{\pi}_D(m_F, m_D - m_F, t_y) = \pi_D(m_D, t_y)$ (recall the remark below Lemma 1), and since $\tilde{\pi}_D(w, t_x, t_y)$ is decreasing in w and in t_x from condition (10), we

[17]Since t_y is fixed in this subsection, we do not include it as an argement of w function.

would have $\tilde{\pi}_D\left(w\left(t_x\right), t_x, t_y\right) < \pi_D\left(m_D, t_y\right)$, implying that there will be no outsourcing, a contradiction. ■

We define $\bar{t}_x = m_D - m_F$ and call $\bar{t}_x$ the prohibitive level of tariff. When $t_x \geq \bar{t}_x$, the equilibrium is non-outsourcing: firm D produces the intermediate good by itself. When $t_x < \bar{t}_x$, the equilibrium is outsourcing: firm D purchases the intermediate good from firm F at price $w(t_x)$, the equilibrium price for the intermediate good. Therefore, if t_x is initially high that deters trade in the intermediate good, we could observe that firm D moves from the non-outsourcing regime to the outsourcing regime as the tariff on the intermediate good decreases.

From Proposition 1, one may think that it should be true that $w\left(t_x\right) + t_x < m_D$ in the outsourcing equilibrium; i.e., firm D would pay less (including the tariff) for the intermediate good when it decides to go outsourcing. However, Proposition 1 is actually more subtle than it appears and, as the next proposition shows, the above conjecture is false.

Proposition 2 *When the outsourcing equilibrium obtains, we have* $w\left(t_x\right) + t_x > m_D$ *and* $\tilde{p}_i\left(w(t_x), t_x, t_y\right) > p_i\left(m_D, t_y\right)$ *for* $i = D, F$.

Proof: From Proposition 1, $t_x < m_D - m_F$ when there is equilibrium outsourcing. Suppose that firm F sets $w = m_D - t_x$. Then we have $\tilde{\pi}_D\left(w, m_D - w, t_y\right) > \pi_D\left(m_D, t_y\right)$ from Lemma 3. Since firm D will accept any offer of w from firm F such that $\tilde{\pi}_D\left(w, t_x, t_y\right) = \pi_D\left(m_D, t_y\right)$, and since $\tilde{\pi}_F\left(w, t_x, t_y\right)$ is increasing in w and $\tilde{\pi}_D\left(w, t_x, t_y\right)$ is decreasing in w, in equilibrium firm F must offer $w(t_x)$ such that $\tilde{\pi}_D\left(w\left(t_x\right), t_x, t_y\right) = \pi_D\left(m_D, t_y\right)$, which implies $w\left(t_x\right) + t_x > m_D$.

Furthermore, since $w\left(t_x\right) + t_x > m_D$ (and $w\left(t_x\right) > m_F$), from Lemma 2 and condition (9) we must have $\tilde{p}_i\left(w(t_x), t_x, t_y\right) > p_i\left(m_D, t_y\right)$. ■

It is surprising that, when moving to outsourcing, firm D actually pays more for the intermediate good than its own cost to produce the good. To understand this result, one needs to recognize that the condition for firm D to decide to go outsourcing is $\tilde{\pi}_D\left(w(t_x), t_x, t_y\right) \geq \pi_D\left(m_D, t_y\right)$ rather than $w\left(t_x\right) + t_x < m_D$. More importantly, notice that firm F would have less incentive to cut its price in the final-good market if it supplies the intermediate good to firm D. This implies that firm D would strictly prefer to buy the intermediate input from firm F if the cost of outsourcing is the same as that of its own production. This then enables firm F to raise the price of the intermediate good. Consequently, the prices of the final products are also higher under outsourcing than under non-outsourcing. Therefore, this kind of outsourcing has a strategic effect: it changes the competition in the final-good market resulting in less competition.

We have shown that strategic outsourcing can arise when trade in the intermediate product is liberalized. Now, if there is already outsourcing in equilibrium, what would be the effects of further trade liberalization in the intermediate good? When $t_x < \bar{t}_x$ and the equilibrium is outsourcing, a further reduction of t_x increases the equilibrium price of the intermediate good, w, but surprisingly, it would also increase what firm D pays for the intermediate good (i.e., $w(t_x) + t_x$) and the prices of the final goods.

Proposition 3 *In the equilibrium of outsourcing, a reduction of t_x increases $w(t_x) + t_x$ (i.e., $|dw(t_x)/dt_x| > 1$) and the prices of the final products.*

Proof:[18] We first recall from the analysis before condition (10) that

$$\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial w} = (\widetilde{p}_D - w - t_x)\left[\frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial p_D} + \frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial p_F}\frac{\partial \widetilde{p}_F(w, t_x, t_y)}{\partial w}\right]$$

Similarly, we can obtain

$$\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial t_x} = (\widetilde{p}_D - w - t_x)\left[\frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial p_D} + \frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial p_F}\frac{\partial \widetilde{p}_F(w, t_x, t_y)}{\partial t_x}\right]$$

Since $\frac{\partial \widetilde{p}_F(w,t_x,t_y)}{\partial w} > \frac{\partial \widetilde{p}_F(w,t_x,t_y)}{\partial t_x} > 0$ from condition (9'), we obtain

$$\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial t_x} < \frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial w} < 0 \tag{12}$$

Now, from Lemma 1, in equilibrium firm F will choose w such that the following condition always holds: $\tilde{\pi}_D(w(t_x), t_x, t_y) = \pi_D(m_D, t_y)$. Differentiating this identity with respect to t_x, we have

$$\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial w}\frac{dw(t_x)}{dt_x} + \frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial t_x} = 0.$$

[18] We owe Yoichi Sugita for this version of proof.

Using (12) we obtain

$$\frac{dw(t_x)}{dt_x} = -\frac{\frac{\partial \tilde{\pi}_D(w,t_x,t_y)}{\partial t_x}}{\frac{\partial \tilde{\pi}_D(w,t_x,t_y)}{\partial w}} < -1, or \frac{d[w(t_x)+t_x]}{dt_x} < 0$$

Now using the above result and condition (9'), we obtain that

$$\begin{aligned} \frac{d\tilde{p}_i(w(t_x),t_x,t_y)}{dt_x} &= \frac{\partial \tilde{p}_i(w,t_x,t_y)}{\partial w}\frac{dw(t_x)}{dt_x} + \frac{\partial \tilde{p}_i(w,t_x,t_y)}{\partial t_x} \\ &< \frac{\partial \tilde{p}_i(w,t_x,t_y)}{\partial w}\frac{dw(t_x)}{dt_x} + \frac{\partial \tilde{p}_i(w,t_x,t_y)}{\partial w} < 0 \blacksquare \end{aligned}$$

To see the intuition behind Proposition 3, consider the following thought experiment. In equilibrium, firm D has the same profit between outsourcing the intermediate good and producing it internally (i.e., $\widetilde{\pi}_D = \pi_D$). Suppose that there is a reduction in t_x. If firm F raises w the same amount as the reduction in t_x, firm $D's$ marginal cost in purchasing from firm F, $w + t_x$, would be unchanged. But since w is higher, firm F now cares more about the profit from selling the intermediate good and hence has less incentive to compete with firm D in the final-product market. As a result, $\widetilde{\pi}_D$ is higher. To restore the condition $\widetilde{\pi}_D = \pi_D$, w will have to increase by more than the reduction in t_x. That is, $w(t_x) + t_x$ will increase with a reduction in t_x. Consequently, the prices for the final good will also be higher. Thus, further trade liberalization in the intermediate good could result in higher prices in both intermediate and final product markets. These results are all verified in the appendix using an example of linear demands.

3.2 Trade liberalization in the final good

In this section we shall focus on the effects of trade liberalization in the final good in the equilibrium of outsourcing. This can be analyzed by examining the effects of a reduction in the tariff of the final good. We first examine the effect on w of a decrease in t_y. To see this, notice that $\widetilde{\pi}_D(w, t_x, t_y)$ and $\pi_D(m_D, t_y)$ are both indirectly affected by t_y but in equilibrium firm F will use w to satisfy that $\widetilde{\pi}_D(w(t_y), t_x, t_y) = \pi_D(m_D, t_y)$.[19] Therefore,

[19] Since t_x is fixed in this subsection, we shall not include it as an argement of w function.

we obtain

$$\frac{dw(t_y)}{dt_y} = -\frac{\frac{\partial \tilde{\pi}_D}{\partial t_y} - \frac{\partial \pi_D}{\partial t_y}}{\frac{\partial \tilde{\pi}_D}{\partial w}}.$$

Since the denominator is negative, we only need to compare $\partial\tilde{\pi}_D/\partial t_y$ with $\partial\pi_D/\partial t_y$ to determine the sign of dw/dt_y. We should note that both $\partial\tilde{\pi}_D/\partial t_y$ and $\partial\pi_D/\partial t_y$ here are obtained with fixed t_x and w. Using the envelope theorem and the first-order conditions (3) and (7), we obtain

$$\begin{aligned}\frac{\partial \tilde{\pi}_D(w, t_x, t_y)}{\partial t_y} &= (\tilde{p}_D - w - t_x)\frac{\partial q_D(\tilde{p}_D, \tilde{p}_F)}{\partial p_F}\frac{\partial \tilde{p}_F(w, t_x, t_y)}{\partial t_y} \\ &= -\frac{q_D(\tilde{p}_D, \tilde{p}_F)}{\frac{\partial q_D(\tilde{p}_D, \tilde{p}_F)}{\partial p_D}}\frac{\partial q_D(\tilde{p}_D, \tilde{p}_F)}{\partial p_F}\frac{\partial \tilde{p}_F(w, t_x, t_y)}{\partial t_y},\end{aligned} \tag{13}$$

$$\begin{aligned}\frac{\partial \pi_D(m_D, t_y)}{\partial t_y} &= (p_D - m_D)\frac{\partial q_D(p_D, p_F)}{\partial p_F}\frac{\partial p_F(m_D, t_y)}{\partial t_y} \\ &= -\frac{q_D(p_D, p_F)}{\frac{\partial q_D(p_D, p_F)}{\partial p_D}}\frac{\partial q_D(p_D, p_F)}{\partial p_F}\frac{\partial p_F(m_D, t_y)}{\partial t_y}.\end{aligned} \tag{14}$$

Since the prices of the final products under outsourcing are different from those under non-outsourcing, in general we cannot compare $\partial\tilde{\pi}_D/\partial t_y$ with $\partial\pi_D/\partial t_y$ without the knowledge of the demand functions. However, for the case of linear demands, we show, in the appendix, that w is independent of t_y. We thus obtain the following proposition:

Proposition 4 *(i) A reduction of t_y reduces (resp. increases) the price of the intermediate product, w, if and only if $\partial\tilde{\pi}_D(w, t_x, t_y)/\partial t_y$ is greater (resp. smaller) than $\partial\pi_D(m_D, t_y)/\partial t_y$. (ii) When demands are linear, a reduction of t_y does not affect w.*

We next investigate the effect on $\tilde{p}_i$ of a decrease in t_y. Noticing that a change in t_y affects w, we obtain

$$\frac{d\tilde{p}_i(w(t_y), t_x, t_y)}{dt_y} = \frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial w}\frac{dw(t_y)}{dt_y} + \frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial t_y}.$$

Using (9) we obtain

$$\frac{d\tilde{p}_i(w(t_y), t_x, t_y)}{dt_y} > 0 \Leftrightarrow \frac{dw(t_y)}{dt_y} > -\frac{\frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial t_y}}{\frac{\partial \tilde{p}_i(w, t_x, t_y)}{\partial w}}.$$

Thus, the effect on $\tilde{p}_i$ of a change in t_y crucially depends on how a change in t_y affects w. from (9) and Proposition 4, it is obvious that in the case of linear demands, a decrease in t_y lowers the prices of the final products. We thus establish the following proposition.

Proposition 5 *(i) A reduction of t_y reduces (resp. increases) $\tilde{p}_i$ if and only if $dw(t_y)/dt_y$ is greater (resp. smaller) than C, where $C \equiv -\frac{\partial \tilde{p}_i(w,t_x,t_y)/\partial t_y}{\partial \tilde{p}_i(w,t_x,t_y)/\partial w} < 0$. (ii) When demands are linear, a reduction of t_y lowers the prices of the final products.*

We should note that in the presence of strategic outsourcing, the effects of trade liberalization in the intermediate-good market could be very different from those in the final-good market. With linear demands, for instance, trade liberalization in the final-good market reduces consumer prices *but* trade liberalization in the intermediate-good market could have an opposite effect.

4. DISCUSSION

The basic point of this paper is to draw attention to a previously unknown consequence of trade liberalization in the intermediate-good market, namely that it can lead to strategic outsourcing that *increases* prices for both intermediate and final goods. The reason for this surprising result is that when a domestic firm purchases the intermediate good from a foreign firm, the two firms will have less incentive to compete in the domestic final-good market because the foreign firm will take into account how its action in the final-good market affects its profit from the intermediate good. A tariff reduction in the intermediate good either enables or enhances this collusive effect. To make our point in a transparent way, we have considered a highly stylized model. Naturally, one wonders to what extent our results are robust. In this section, we discuss some alternative assumptions to gain insight on this issue. In particular, we are interested in how our analysis would be affected if firms were to compete in quantities or if firm F did not have all the bargaining power in setting the price of the intermediate good.

If firms D and F choose quantities simultaneously in the market of a homogeneous final product, as in a traditional Cournot model, then, since firm $D's$ output is taken as given when firm F chooses its output, firm F cannot incorporate the effect on the sale of intermediate good by its actions in the final-good market. Thus, the collusive effect identified in our analysis would not arise in a Cournot model.[20] However, it seems more plausible that firm F would consider how its strategic action in the final-good market affects its profit from the intermediate-good market; and if that is the case, the Cournot assumption would seem inappropriate for our analysis. However, within the framework of quantity competition, the collusive effect of strategic outsourcing could also arise if firm F is a Stackelberg leader in setting the quantity in the final-good market. As a Stackelberg leader, firm F would then incorporate the effect of its action in the final-good market on its profit of selling the intermediate good. Then, the collusive incentive of strategic outsourcing can again arise.

In our model, firm F is the only integrated foreign firm that has the lower marginal cost to produce the intermediate good and hence we have assumed that it has the market power to set its price for the intermediate good. In equilibrium, firm F chooses w such that $\widetilde{\pi}_D(w, t_x, t_y) = \pi_D(m_D, t_y)$, or firm D is just indifferent between outsourcing and non-outsourcing. While our assumption about firm $F's$ ability to set w allows us to derive the results in a most clear way, this assumption is not essential to the basic insight of our analysis. Suppose that the price for the intermediate good is negotiated between firms F and D, and firm F does not have all the bargaining power (cannot make a "take-it-or-leave-it" offer). Then, when $t_x < m_D - m_F$, or $m_F + t_x < m_D$, there is surplus to be shared between firms F and D when firm D purchases the input from firm F. Thus, under any bargaining procedure (such as Nash bargaining) that allows the two parties to share the surplus, there will be equilibrium outsourcing, and Proposition 1 will continue to hold.[21] Furthermore, as long as firm $F's$ share of the surplus is not zero, or $w > m_F$, the collusive effect identified in our analysis will again arise, reducing the possible benefits from trade

[20] As in Spencer and Jones (1991,1992), vertical supply could occur under Cournot competitition but there is no collusive effect.

[21] To model the bargaining formally, one would need to consider the sharing of the increase in profits due to outsoucing. But since profits are determined endogenously, depending on w, the formal modeling of bargaining appears to be quite complicated. We hope, however, that our informal discussion can shed enough light on this issue.

liberalization in the intermediate market. Notice that if $m_F < m_D - t_x = w$, both firms D and F would be strictly better off from outsourcing than non-outsourcing: for firm D, its effective input price would be $w + t_x = m_D$, the same as producing the input internally, but its profit would be higher due to the collusive effect; for firm F, it would make extra profit from selling the intermediate good in addition to the increased profit from the final product due to the collusive effect.[22] In this case, even though the intermediate input price for firm D is not increased, there is definitely an increase in the final-good prices. Therefore, by continuity, if $m_F < m_D - t_x$ and firm F has sufficient bargaining power so that the price that it charges firm D, w, is not too much below $m_D - t_x$, equilibrium outsourcing will lead to higher final-good prices even it reduces the intermediate-input price. In other words, the collusive effect may dominate the effect of lower input price to result in higher prices for the final product. However, if firm $F's$ bargaining power is sufficiently small such that w is sufficiently close to m_F, the direct effect of cost reduction will result in lower prices for the final product.

Thus, adopting a general bargaining approach in the determination of the input price will not change our result concerning when equilibrium outsourcing would occur, neither will it change the collusive effect that arises with outsourcing. However, our result that outsourcing leads to higher prices for both the intermediate and the final goods does depend on the bargaining power of firm F: when firm $F's$ bargaining power is sufficiently large, outsourcing leads to higher prices in both markets; when firm $F's$ bargaining power is in some intermediate range, outsourcing can lead to lower intermediate-good price but higher final-good price; and when firm $F's$ bargaining power is sufficiently low, outsourcing leads to lower prices in both markets. To the extent that firm $F's$ bargaining power is likely to be lower when it faces more competition from other producers in the intermediate market, the preceding discussion has an interesting policy implication: there is a need for coordination between trade liberalization and competition policies. To realize the potential benefits from trade liberalization in the intermediate-goods markets, it may be necessary to introduce

[22] By continuity, both firms D and F are strictly better off with outsourcing when w is above but sufficiently close to $m_D - t_x$.

measures (or market reform) that would increase competition in these markets.

There are other ways to extend or to interpret our model. For instance, instead of assuming that in the non-outsourcing equilibrium firm D produces the intermediate good by itself at cost m_D, we could assume that firm D initially purchases the intermediate good from a competitive domestic supplier at price m_D. With trade liberalization, firm D moves to international outsourcing, switching its purchase of the intermediate good from the domestic supplier to firm F. Our results would not be changed with this modification of the model. On the other hand, the timing assumption is important for our analysis, as it is in the international trade literature on profit-shifting models (e.g., Arvan, 1991; and Hwang and Schulman, 1993). If, instead of our assumption, the input purchase decision is made after final-good prices are set, then firm F would only be able to sell to firm D at $w = m_D - t_x$. However, if $t_x < m_D - m_F$, outsourcing would again occur, and thus Proposition 1 would continue to hold. Furthermore, when there is outsourcing, the collusive effect identified in our analysis would again arise, and hence the basic insight of our analysis would be valid. In fact, the analysis in this case would be similar to the analysis earlier when both firms have some bargaining power in determining the price of the intermediate good; while outsourcing cannot raise intermediate good price, it can raise the prices of the final good.

5. CONCLUDING REMARKS

In this paper we have identified a strategic incentive for international outsourcing, which arises from multi-market interactions among firms. It is shown that trade liberalization may create opportunities for multi-market interdependence and cause strategic outsourcing to occur. Unlike the outsourcing motivated by cost saving, strategic outsourcing can have a collusive effect and raise prices in the intermediate-good and final-good markets. In the presence of strategic outsourcing, further trade liberalization in the intermediate-product market could further increase prices in both markets. Trade liberalization in the intermediate good market could have a very different effect compared with trade liberalization in the final good market.

It is well known that the majority of total world trade are intermediate products/components and this trend has been growing continuously. More importantly, trade in intermediate products is concentrated in relatively a few product groups. Within the OECD countries, for example, "4 of the 44 SITC product groups account jointly for over 70 percent of total trade in components with parts of motor vehicles alone accounting for over 91 billion, or about one-quarter of the total exchange in these goods " (Yeats, 2001). Some of the markets for key inputs/components have significant market power. Thus, the analysis in the current paper is relevant and may have important policy implications. As discussed in Section 4, the collusive effects of strategic outsourcing depend on the foreign firm having strong market power in setting the price of the intermediate good. Therefore, in order to achieve its potential benefits, trade liberalization in intermediate-good markets may need be accompanied by market reforms that increase competition.

In our study, we have taken tariff rates set by governments as given parameters in order to focus on the strategic aspect of outsourcing. The comparative-statics analysis on these parameters then enables us to study the effects of trade liberalization in the presence of strategic outsourcing. More generally, one might want to extend our framework to consider effective protection and optimal trade policies by governments in vertically related markets. This remains an interesting issue for future research.

APPENDIX

For illustration of our results, we shall consider a linear-demand example in this appendix. Suppose that the demand function is given by:

$$q_i(p_i, p_j) = 1 - p_i + \beta(p_j - p_i);\ i, j = D, F,\ \beta \in (0, \infty). \tag{15}$$

Following (3) and (4), we obtain both firms' equilibrium prices of the final product under non-outsourcing:

$$p_D(m_D, t_y) = \frac{2 + 3\beta + 2(1+\beta)^2 m_D + \beta(1+\beta)(m_F + t_y)}{(2+\beta)(2+3\beta)}$$

$$p_F(m_D, t_y) = \frac{2 + 3\beta + 2(1+\beta)^2 (m_F + t_y) + \beta(1+\beta)m_D}{(2+\beta)(2+3\beta)}$$

Then the equilibrium outputs under non-outsourcing are

$$q_D(p_D, p_F) = \frac{(1+\beta)[2 + 3\beta - (2 + 4\beta + \beta^2)m_D + \beta(1+\beta)(m_F + t_y)]}{(2+\beta)(2+3\beta)}$$

$$q_F(p_F, p_D) = \frac{(1+\beta)[2 + 3\beta - (2 + 4\beta + \beta^2)(m_F + t_y) + \beta(1+\beta)m_D]}{(2+\beta)(2+3\beta)}.$$

Using (1) - (4), we can obtain the equilibrium profits for firms D and F since $\pi_i(m_D, t_y) = q_i^2(p_i, p_i)/(1+\beta)$. For example,

$$\pi_D(m_D, t_y) = (1+\beta)\frac{[2 + 3\beta - (2 + 4\beta + \beta^2)m_D + \beta(1+\beta)(m_F + t_y)]^2}{(2+\beta)^2(2+3\beta)^2}$$

From (7) and (8), we obtain both firms' corresponding equilibrium prices under outsourcing:

$$\widetilde{p}_D(w, t_x, t_y) = \frac{2(1 + w + t_x) + \beta\{3 + m_F + t_y + 4(w + t_x) + \beta[t_y - t_x + 3(w + t_x)]\}}{(2+\beta)(2+3\beta)}$$

$$\begin{aligned}\widetilde{p}_F(w, t_x, p_y) \quad = \quad & \frac{\beta\{2(2+\beta)(m_F + t_y) - 2(1+\beta)(m_F + t_x) + 3[1 + w + t_x + \beta(w + t_x)]\}}{(2+\beta)(2+3\beta)} \\ & + \frac{2(1 + m_F + t_y)}{(2+\beta)(2+3\beta)}.\end{aligned}$$

Then the equilibrium outputs under outsourcing are

$$q_D(\widetilde{p}_D, \widetilde{p}_F) = \frac{(1+\beta)\{\beta^2(t_y - t_x) + \beta[3 + m_F + t_y - 4(w + t_x)] - 2(w + t_x - 1)\}}{(2+\beta)(2+3\beta)}$$

$$\begin{aligned} q_F(\widetilde{p}_F, \widetilde{p}_D) &= \frac{\beta\{5 - 4m_F + t_x - 6t_y + \beta[3 - m_F + (2+\beta)t_x - (5+\beta)t_y - 2w] - w\}}{(2+\beta)(2+3\beta)} \\ &\quad + \frac{2(1 - m_F - t_y)}{(2+\beta)(2+3\beta)}. \end{aligned}$$

Using (5) and (7), the equilibrium profit for firm D becomes

$$\begin{aligned} \widetilde{\pi}_D(w, t_x, t_y) &= (\frac{1}{1+\beta}) q_D^2(\widetilde{p}_D, \widetilde{p}_F) \\ &= (1+\beta)\frac{\{\beta^2(t_y - t_x) + \beta[3 + m_F + t_y - 4(w + t_x)] - 2(w + t_x - 1)\}^2}{(2+\beta)^2(2+3\beta)^2}. \end{aligned}$$

Therefore, from Lemma 1 the equilibrium price for the intermediate product is obtained by setting $\widetilde{\pi}_D(w, t_x, t_y)$ equal to $\pi_D(m_D, t_y)$, which gives

$$w(t_x) + t_x = m_D + \frac{\beta^2(m_D - m_F - t_x)}{4\beta + 2} \tag{16}$$

Notice that $w(t_x) + t_x > m_D$ because $t_x < m_D - m_F$, and it is straightforward to show that $dw/dt_x = -(\beta^2 + 4\beta + 2)/(4\beta + 2) < -1$, $d\widetilde{p}_D/dt_x < 0$ and $d\widetilde{p}_F/dt_x < 0$. Also, w does not depend on t_y, and $d\widetilde{p}_D/dt_y > 0$ and $d\widetilde{p}_F/dt_y > 0$. This can also be verified by the fact that $\partial\widetilde{\pi}_D/\partial t_y = \partial\pi_D/\partial t_y$.[23]

Also, we obtain that

$$\frac{\partial\tilde{\pi}_D(w, t_x, t_y)}{\partial w} = (\frac{2}{1+\beta}) q_D(\widetilde{p}_D, \widetilde{p}_F) \frac{\partial q_D(\widetilde{p}_D, \widetilde{p}_F)}{\partial w} = \frac{-4(2\beta+1)}{(2+\beta)(2+3\beta)} q_D(\widetilde{p}_D, \widetilde{p}_F)$$

[23] These results actually hold for general linear-demand functions. We use (15) in order to reduce the number of parameters for this excercise. For example, to show that $\partial\widetilde{\pi}_D/\partial t_y = \partial\pi_D/\partial t_y$ holds with general linear-demand functions, suppose $q_i(p_i, p_j) = a_i - b_i p_i + c_i p_j$ $(i, j = D, F)$. Then, the FOCs under outsourcing (7) and (8) become

$$\begin{aligned} a_D - b_D\widetilde{p}_D + c_D\widetilde{p}_F - b_D(\widetilde{p}_D - w - t_x) &= 0 \\ a_F - b_F\widetilde{p}_F + c_F\widetilde{p}_D - b_F(\widetilde{p}_F - m_F - t_y) + (w - m_F)c_D &= 0 \end{aligned}$$

Differentiating these two equations with respective to t_y and solving for $\partial\widetilde{p}_F(w, t_x, t_y)/\partial t_y$, we obtain that $\partial\widetilde{p}_F(w, t_x, t_y)/\partial t_y = 2b_D b_F/\Omega$,where $\Omega \equiv 4b_D b_F - c_D c_F > 0$. On the other hand, the FOCs without

$$\frac{\partial\tilde{\pi}_D\left(w,t_x,t_y\right)}{\partial t_x}=(\frac{2}{1+\beta})q_D(\widetilde{p}_D,\widetilde{p}_F)\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial t_x}=\frac{-2(\beta^2+4\beta+2)}{(2+\beta)(2+3\beta)}q_D(\widetilde{p}_D,\widetilde{p}_F)$$

which are negative for any positive level of output. These are condition (10) that is assumed in the paper for the general functional form.

Finally, using (6) and (8), the equilibrium profit for firm F becomes

$$\widetilde{\pi}_F(w,t_x,t_y)=(\frac{1}{1+\beta})q_F^2(\widetilde{p}_F,\widetilde{p}_D)+(\frac{\beta}{1+\beta})(w-m_F)q_F+(w-m_F)q_D(\widetilde{p}_D,\widetilde{p}_F)$$

To show that condition (11) holds, we derive that (after rearranging and using (16))

$$\begin{aligned}\frac{\partial\tilde{\pi}_F\left(w,t_x,t_y\right)}{\partial w} &= (\frac{2}{1+\beta})q_F(\widetilde{p}_F,\widetilde{p}_D)\frac{\partial q_F(\widetilde{p}_F,\widetilde{p}_D)}{\partial w}+(\frac{\beta}{1+\beta})q_F+q_D\\ &\quad+(w-m_F)[(\frac{\beta}{1+\beta})\frac{\partial q_F(\widetilde{p}_F,\widetilde{p}_D)}{\partial w}+\frac{\partial q_D(\widetilde{p}_D,\widetilde{p}_F)}{\partial w}]\\ &= q_D(\widetilde{p}_D,\widetilde{p}_F)+\frac{(3\beta^2+4\beta+2)[\beta q_F(\widetilde{p}_F,\widetilde{p}_D)-(\frac{\beta^2+4\beta+2}{2})(m_D-m_F-t_x)]}{(1+\beta)(2+\beta)(2+3\beta)}\end{aligned}$$

In the following, we show that there exist a set of parameter vaules with which condition (11) holds. Suppose that $m_F=t_y=0$ and $\beta=1$, then $\partial\tilde{\pi}_F/\partial w>0$ if and only if

$$w<\frac{65}{132}-\frac{16}{33}t_x. \tag{17}$$

From (16) we have $w=\frac{7m_D}{6}-\frac{7}{6}t_x$. Thus, for $0<m_D<65/154$, both (16) and (17) hold. All the other results can also be verified including $q^D(\widetilde{p}_D,\widetilde{p}_F)>0$ and $q^F(\widetilde{p}_F,\widetilde{p}_D)>0$.

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outsourcing (3) and (4) become

$$\begin{aligned}a_D-b_Dp_D+c_Dp_F-b_D(p_D-m_D) &= 0\\ a_F-b_Fp_F+c_Fp_D-b_F(p_F-m_F-t_y) &= 0\end{aligned}$$

Applying similar methods, we also obtain that $\partial p_F\left(m_D,t_y\right)/\partial t_y=2b_Db_F/\Omega$.

Now notice that $\partial q_D(\tilde{p}_D,\tilde{p}_F)/\partial p_F = \partial q_D(p_D,p_F)/\partial p_F = c_D$ and $\partial q_D(\tilde{p}_D,\tilde{p}_F)/\partial p_D = \partial q_D(p_D,p_F)/\partial p_D = -b_D$. Moreover, since $\widetilde{\pi}_D(w\left(t_x,t_y\right),t_x,t_y)=\pi_D(m_D,t_y)$, we have $q_D(\tilde{p}_D,\tilde{p}_F) = q_D(p_D,p_F)$ because $\widetilde{\pi}_D(w,t_x,t_y)=q_D^2(\widetilde{p}_D,\widetilde{p}_F)/b_D$ and $\pi_D(w,t_x,t_y)=q_D^2(p_D,p_D)/b_D$. Therefore, from (13) and (14), we have $\partial\tilde{\pi}_D/\partial t_y=\partial\pi_D/\partial t_y$, which is the result for linear demands in part (ii) of Proposition 4.

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