International Collaborations

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Abstract

Over the last two decades there has been a tremendous increase in collaboration among competing firms. A large fraction of these collaborations are international (i.e., among firms from different countries). Competitors often collaborate by sharing a part of their value-creating activities such as technology development, product design and distribution. This saves production costs. However the cost savings comes at the expense of reduction in product distinctiveness since these activities (see above) are also important for creating product distinctiveness. This paper explores the relationship between trade cost and incentives to collaborate in a two-stage model with collaboration decisions followed by price competition. We also examine the welfare consequences of such collaboration. We find that an increase in trade costs makes collaboration more likely. Higher trade cost lowers competition which enables the firms to forego some distinctiveness in exchange of fixed cost savings. Furthermore, we demonstrate that, contrary to standard intuition, higher trade cost could enhance consumers' welfare by inducing competitors to collaborate. We extend our model to incorporate communication costs and endogenous location choice by the firms. Locating in the same country increases competition between firms but lowers the communication cost (if the firms collaborate). In this extension, an increase in trade cost continues to encourage collaboration provided the loss in product distinctiveness from collaboration is higher than a certain threshold. However we find that below that threshold level an increase in trade costs can discourage collaboration. Under both circumstances, an increase in trade cost can be welfare improving.

Keywords: competitor collaboration, location choice, product distinctiveness, trade cost

JEL classification: D40, F12, F13, L13, L24, M20, M31

1. Introduction

Firms collaborate in a variety of ways. The most common example in the industrial organisation literature is that of price collusion, where firms collaborate on prices to reduce price competition. In the event of a merger, the merged firms can collaborate on output as well as prices. These kinds of collaboration take place at the market competition stage for products. However, collaborations may also take place before market competition. The last two decades have seen a phenomenal growth of globalization in the form of collaboration across competing firms. Many of these collaborations are between firms located in different countries.

This paper investigates a form of collaboration between firms located in different countries, by examining cross-border collaboration in value-creating activities that take place before market competition such as technology development, product design and distribution. Such collaboration reduces cost but it also reduces product distinctiveness. One important feature that we should note is that a typical strategic alliance (SA) may or may not involve equity sharing.[1] Due to the shift towards non-equity alliances in the last decade, our focus is on alliances where there is no equity sharing between participants.[2] The firms remain separate identities

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[1]Terpstra and Simonin (1993) classified SAs into four types: (i) contractual agreements between two parties for which no legal entity is created and there is no purchase of equity between parties, (ii) equity participation which involves the acquisition of equity in one firm by another, (iii) joint ventures in which a separate legal entity is created and (iv) consortia, a collaborative arrangement among three or more parties, regardless of the equity structure. This thesis focuses on (i).

[2]Caloghirou, Ioannides, and Vonortas, (2003) reported a steady decline in the use of equity agreements on a global basis. Whereas equity joint ventures accounted for most of the alliances in the 1970s (over 90% in 1977),

and remain competitors in the product market.

Recent evidence suggests that even firms that compete fiercely in the product market often co-operate outside it through alliances and collaboration (see Caloghirou, Ioannides, and Vonortas, 2003; Chen and Ross, 2000; and Morasch, 2000a). In recent years the incidence and importance of collaborations among competing firms have increased tremendously (Oster, 1994). A significant number of recent competitor collaboration agreements have been between international firms. Such collaborations are prominent in several industries including the:

- Automobile industry−for example, Renault and Nissan share key components−such as engines, axles and transmissions−and save on product development costs. The two manufacturers have jointly developed a common platform for the Nissan Micra and the Renault Clio. Such platform sharing arrangements are also observed between GM and Daimler-Chrysler and other carmakers.

- Semiconductor industry−for example, IBM, Sony Group and Toshiba collaborated in developing a high-performance microprocessor (named Cell) for four years since 2001.[3]

- Liquid crystal display (LCD) industry−for example, Samsung and Sony jointly established a company to manufacture LCD panels for flat panel TVs. The jointly established manufacturer provides the two companies with LCD panels for each company's LCD TVs.[4]

Nevertheless, sharing a part of their value creating activities affects one of the key bases of product differentiation discussed in Caves and Williamson (1985) leading to a decline in product distinctiveness. As illustrated in the above examples, by sharing key components such as engines, high-performance microprocessors and LCD panels, competitors can save on costs for technology development, product design and manufacturing at the expense of reducing their product distinctiveness.

As shown in the above mentioned examples, a significant number of the recent collaboration agreements are between firms from different countries. The OECD Report (2001) noted a significant growth in the number of cross-border strategic alliances in the 1990s (from around 830 to 4,520 between 1989 and 1999). Between 1980 and 1990, Japanese firms and American firms agreed on over 500 collaboration arrangements (Oster, 1994). Kang and Sakai (2000) have found that the number of international collaborations grew more than five-fold between 1989 and 1999. Hagedoorn and Narura (1997) suggest that about 65% of collaborative arrangements in Japan, North America and Europe are international alliances. Additionally, 41% of all alliances by US firms have been internationally oriented, whereas in Spain, 96% of Spanish alliances have involved at least one non-Spanish firm.

The phenomenon of international alliances and collaborations has attracted substantial attention from scholars and researchers. Although competitors collaborate in a variety of ways and for many reasons in reality, most previous papers on theoretical analysis of competitor collaborations have primarily focused on the context of research joint ventures in oligopolies with research and development (R&D) spillovers (see, e.g., Motta, 1996; Steurs, 1995; and

the 1980s and 1990s showed a clear trend towards the use of more flexible, fast-to-build contractual agreements (non-equity based partnerships accounted for over 90% of total alliances in 1998).

[3] http://www.toshiba.co.jp/about/press/2005_02/pr3101.htm, visited June 15, 2006.

[4] http://news.com.com/Japanese+makers+forge+1+billion+LCD+alliance/2100-1041_3-5331665.html, visited February 20, 2008.

Suzumura, 1992). Katz (1986) explored a four-stage model in which firms in an industry form a co-operative (cost reducing) R&D agreement and determine rules to share the R&D cost and output before competing against each other by choosing levels of their R&D efforts and production outputs. D'Aspremont and Jacquemin (1988) considered a two-stage model in which each firm determines the level of its cost reducing R&D (with spillover) investment, and then chooses the level of its production. Here the co-operative R&D is modelled as the joint determination of the levels of the firms' R&D investments. In the context of stochastic R&D, Choi (1993) captured the idea that a co-operative R&D agreement may intensify product-market competition among participants in his two-firm model. Cabral (2000) and Martin (1995) studied the impact of co-operative R&D and showed that it may lead to collusive behaviour in the product market and thereby reduce competition. Motta (1996) and Steurs (1995) extended the field of inquiry on research joint ventures in the R&D spillovers literature by studying the game in an international setting.

Other examples of different types of collaboration include Chen and Ross (2000). They analysed the entry deterrence effect of a facility sharing alliance, common in the airline industry, and found that an alliance may reduce competition, and subsequently welfare, by inducing an entrant to enter the market without investment in new production capacity even if the incumbent and entrant are not direct competitors. Morasch (2000) studied collaboration in the form of an input joint venture as a substitute for strategic trade policy. In his model, SAs reduce competition in the product market unless several alliances are formed and found a condition when permitting SAs and using strategic trade policy yields exactly the same outcome. Chen and Ross (2003) considered a joint venture in which two parent firms competing in a downstream market share ownership of a facility that produces an important input and found that joint ventures can effective reproduce the effects of a full scale merger of the parents. Chen (2003) focused on the cost saving aspect of cross-border collaborations. He studied international alliances, in the form of bilateral supply and distribution agreements, as an alternative to exporting in the context of homogenous-product Cournot duopoly in an international setting (similar to the "reciprocal dumping" model by Brander and Krugman, 1983). The focus was on cost savings by sharing a distribution network−an alliance where product characteristics were not affected. He found that when such a choice is available, both firms prefer a SA to direct exporting but consumers do not reap any benefits from the cost savings generated by the SA.

Although these studies provide insights about many forms of collaboration across the value chain (i.e., cross-border mergers, information sharing, bilateral supply and distribution agreements, facility sharing, input joint venture, and co-operative R&D arrangement), they all assume that product characteristics are fixed. Several notable papers study the trade-off from collaborations−fixed cost savings and reduction in product distinctiveness−which underpins a large number of real world collaborations. Krishnan and Gupta (2001) discussed the complexity of platform based product development by comparing its costs and benefits. Lambertini, Poddar, and Sasaki (2003) studied collaboration in the form of research joint ventures. They focused on firms' cost savings for product innovation when developing similar products. Ghosh and Morita (2006) investigated the managerial implications and economic consequences of collaboration in the form of platform sharing. In their model, firms can save on fixed costs for platform development at the expense of reduced product distinctiveness. They considered both horizontal and vertical product differentiation and showed that platform sharing across firms can make consumers worse off if firms co-operate in their product development processes to maximise their joint profit. Nevertheless, platform sharing can benefit consumers because it intensifies competition (horizontal differentiation model) and because it increases the quality of the lower-end product (vertical differentiation model). Recently, Ghosh and Morita (2008) analysed the economic consequences of competitor collaborations in the presence of a non-collaborator using a location framework. They showed that contrary to standard belief, partial ownership agreement can benefit some consumers because it softens competition by inducing firms to collaborate. Although the trade-off from collaborations in fixed cost savings and reduction in product distinctiveness have received considerable attention in the theoretical literature, none have studied this kind of collaboration in an international context.

This paper extends the studies above by studying this class of collaboration in the international context. Building on Ghosh and Morita (2006), we develop a model of international collaboration where firms from different countries collaborate in the product development stage such as technology development, product design and distribution,[5] thus saving on costs but reducing product distinctiveness.[6] We examine the incentives to collaborate in equilibrium, study the effect of a change in tariff/trade cost on incentives to collaborate and analyse the welfare consequences. Then, we extend the game by incorporating a country location choice before the collaboration decision. In both cases, we find that contrary to standard international trade results, an increase in trade cost can result in higher consumer welfare with the possibility of collaboration.

An outline of the model is as follows: Suppose there are two countries denoted by 1 and 2, possibly of different size, each with one national firm. In addition to production costs, each firm incurs a trade cost $t > 0$ per unit of export and a fixed product development cost F. Firm 1 is located in country 1 and firm 2 is located in country 2. Firms decide co-operatively whether to collaborate or not. Collaboration (i) reduces fixed product development costs for each firm from F to $\frac{F}{2}$ and (ii) increases product substitutability. If firms do not collaborate, they incur the full product development cost F. After collaboration decisions, firms compete on price.

The extended model introduces the location decision node prior to collaboration decisions. Firm 1's location is assumed fixed in country 1 and firm 2 decides whether to be located in country 1 or 2. We assume that collaboration requires co-location due to (i) joint investment in infrastructures or key assets, (ii) benefits from knowledge spillovers and (iii) savings from communication cost of collaboration. If firms do not collaborate they do not need to co-ordinate and can choose to be located anywhere. After location choices and collaboration decisions, firms compete on price.

In the standard model, we find that an increase in trade costs encourages collaboration. As trade cost increases, the loss from collaboration declines and the threshold where collaboration occurs rises. This creates the possibility that firms might switch collaboration decisions after an increase in trade costs. This result yields rich welfare implications. Although an increase in trade costs creates additional wastage cost which reduces consumer surplus, a reduction in product distinctiveness as a result of collaboration reduces prices and benefits consumers. With the possibility of collaboration, overall consumer surplus can increase as a result of higher trade costs.

In the extended model, we find that an increase in trade costs can either encourage or discourage collaboration. In particular, an increase in trade costs encourages collaboration if fixed cost saving is high and discourages collaboration if fixed cost saving is low. When collaboration requires co-location, both of these outcomes can lead to higher consumer surplus

[5] This is based on a value-chain model proposed by McKinsey and Company (Grant, 1991; Barney, 2002).

[6] Value creation costs are reduced via collaboration.

given that firms switch collaboration decisions. We find that consumer surplus is higher when firms are located in different countries. In the case where an increase in trade costs encourages collaboration, overall consumer surplus increases for the same reason as for the standard model. In the case where an increase in trade costs discourages collaboration, overall consumer surplus increases because firms switch from being co-located to being located in different countries.

Given that collaboration reduces product distinctiveness, firms will naturally collaborate when the loss in profits due to lower product distinctiveness is lower than the benefit of collaboration. Our results suggest that when co-ordination costs of collaboration (which are strictly positive only when firms are in different countries) are lower the threshold rises as tariff/trade cost increases. That is, a reduction in tariffs/trade costs increases the incentives to collaborate. Though collaboration reduces product distinctiveness, which is bad for consumers, it also intensifies competition, which is good for consumers. In our framework the latter effect dominates the former and hence we find that collaboration benefits the consumers. This in turn creates a potentially beneficial role for tariffs. An increase in the tariff rate can raise consumer surplus by inducing firms to collaborate. When co-ordination costs of collaboration are so high that firms have to be located in the same country for collaboration, an increase in trade costs might lower the incentives for collaboration (this depends on fixed costs). In the extended model, we find two interesting outcomes where an increase in trade costs raises consumer welfare. In particular, we find that (i) an increase in trade costs induces firms to collaborate, which leads to higher consumer welfare due to lower prices, and (ii) an increase in trade cost discourages collaboration, which results in higher consumer welfare because firms are located in different countries.

Our results capture the connection between firms' collaboration decision and tariff which provides a new perspective on welfare consequences of trade liberalisation. Our findings suggest that policy makers should carefully investigate the welfare consequences of a tariff reduction. In the standard model where collaboration does not require co-location, a reduction in tariff rate may discourage collaboration and reduce consumer surplus. In the extended model where collaboration requires co-location, we have shown that depending on the magnitude of fixed cost saving, a reduction in tariff may encourage or discourage collaboration. In both cases, consumer surplus may decrease as a result of trade liberalisation.

2. The Model

We develop an international, differentiated, product−duopoly model with the possibility of collaboration between firms; collaboration reduces product distinctiveness and fixed costs. First we study the trade-off between product distinctiveness and fixed cost savings from collaboration. Then we investigate how an increase in trade costs affects the collaboration decision and consumer welfare. Our analysis in this section assumes that firms are located in different countries.

Consider an industry consisting of two firms, firm 1 and firm 2, each producing a differentiated good. There are two countries−1 and 2−and the markets are segmented. Firm 1 is located in country 1 and serves country 2 through exports whilst firm 2 is located in country 2 and exports to country 1. Both firms sell their products in both countries.

In each country j, there is a continuum of consumers of the same type. The representative consumer's preference is described by the utility function, $U(q_{1j}, q_{2j}) + q_0$, where q_0 is the numeraire good,

$$U(q_{1j}, q_{2j}) = a(q_{1j} + q_{2j}) - \frac{(q_{1j}^2 + 2\gamma q_{1j} q_{2j} + q_{2j}^2)}{2}, \tag{2..1}$$

and q_{ij} denotes firm i's quantity sold in country j. Dixit (1979) was the first to use this utility function to analyse entry barriers in a duopoly. Subsequently it has been used by Singh and Vives (1984), Qiu (1997) and several papers in the differentiated oligopoly literature. The parameter γ captures the extent of product differentiation. We restrict $\gamma \in (0, 1)$. $\gamma = 0$ means that products are independent; $\gamma = 1$ means that products are perfect substitutes; $\gamma \in (0, 1)$ means that products are imperfect substitutes. As γ increases, the degree of product differentiation decreases. Corresponding to this utility specification, the inverse demand function for firm 1 and 2's products in country j are:

$$p_{1j} = a - q_{1j} - \gamma q_{2j}, \ j = 1, 2, \tag{2..2}$$

$$p_{2j} = a - q_{2j} - \gamma q_{1j}, \ j = 1, 2. \tag{2..3}$$

where p_{ij} denotes firm i's price in country $j = \{1, 2\}$. Inverting the inverse demand yields the direct demand:

$$q_{1j} = \frac{(a(1-\gamma) + \gamma p_{2j} - p_{1j})}{(1-\gamma^2)} \equiv q_{1j}(p_{1j}, p_{2j}), \tag{2..4}$$

$$q_{2j} = \frac{(a(1-\gamma) + \gamma p_{1j} - p_{2j})}{(1-\gamma^2)} \equiv q_{2j}(p_{1j}, p_{2j}) \tag{2..5}$$

where $a > 0$. The direct demand for firm i is decreasing in its own price and increasing in its rival's price. Similar to Ghosh and Morita (2006), one aspect of the collaboration in our framework is the reduction in product distinctiveness. In the absence of collaboration, $\gamma = \gamma_0$, where $\gamma_0 \in (0, 1)$. When firms collaborate, product distinctiveness declines, which we capture by an increase in γ from γ_0 to $\gamma_0 + x$ where $x \in (0, 1 - \gamma_0)$.[7] The parameter $x \in (0, 1 - \gamma_0)$ captures the degree of loss in product distinctiveness due to collaboration.

Firms have three types of costs. The first is the variable production cost. For simplicity, we assume that both firms have the same production technology and the marginal cost of production is zero. The second is the fixed cost. Firm i must incur a fixed product design cost denoted by $F_i(> 0)$. This cost is lower if firms collaborate. The third type of cost is the per unit trade cost denoted by t, which can be interpreted as transportation cost or tariff.

Firms engage in a two-stage game, which we describe below:

Stage 1 [Collaboration decision]: Firms 1 and 2 decide jointly whether or not to collaborate. By collaborating, both firms save on fixed costs at the expense of loss in product distinctiveness. If firms do not collaborate, $\gamma = \gamma_0 \in (0, 1)$ and $F_i = F$ where $i = 1, 2$. Conversely, if firms collaborate, then $\gamma = \gamma_0 + x$ and $F_i = \frac{F}{2}$. We consider a game where both firms maximise profits and competitor collaboration takes place if and only if two firms mutually agree to collaborate.

Stage 2 [Product market competition]: Firms compete in Bertrand fashion. Given the collaboration decision in stage 1, each firm i chooses price p_{ij} to maximise its own profits in country j, taking its rival's price as given.

[7]Because the direct demand functions are not defined for the case of $\gamma = 1$, we will not be analysing the case of perfect substitutes.

3. Analysis

The game described above has two Stage 2 subgames. The first is where firms 1 and 2 collaborate in Stage 1 (collaboration subgame). The second is where firms do not collaborate in Stage 1 (non-collaboration subgame). An analysis of these subgames provides the equilibrium profits and quantities, which impact the collaboration decision in Stage 1. Then, we derive an equilibrium of the entire game by solving for the equilibrium in Stage 1 using backward induction. We consider an equilibrium in which the two firms jointly decide whether or not to collaborate at Stage 1 so that each firm's profit in the subsequent symmetric Stage 2 equilibrium is maximised. For simplicity, we assume that if firms are indifferent between collaborating and not collaborating, they choose to collaborate.

In Stage 2, firm 1 chooses p_{1j} to maximise $\sum_{j=1,2}[p_{1j} - c_{1j}]q_{1j}(p_{1j}, p_{2j})$, where

$$c_{1j} = \begin{cases} c & \text{if } j = 1 \\ c + t & \text{if } j = 2. \end{cases}$$

Given that the markets are segmented and there is a trade cost $t > 0$, we get two distinct equilibrium prices , quantities and profits for each firm, one for the domestic market and another for the foreign market. Thus, we can obtain:

$$p_{1j}(\gamma, t) = \begin{cases} \frac{(2a+t\gamma-a\gamma^2-a\gamma)}{(4-\gamma^2)} & \text{if } j = 1 \\ \frac{(2a+2t-a\gamma^2-a\gamma)}{(4-\gamma^2)} & \text{if } j = 2, \end{cases} \tag{3..1}$$

$$q_{1j}(\gamma, t) = \begin{cases} \frac{(2a+t\gamma-a\gamma^2-a\gamma)}{(1-\gamma^2)(4-\gamma^2)} & \text{if } j = 1 \\ \frac{(2a+t\gamma^2-a\gamma^2-a\gamma-2t)}{(1-\gamma^2)(4-\gamma^2)} & \text{if } j = 2, \end{cases} \tag{3..2}$$

and

$$\pi_{1j}(\gamma, t) = \begin{cases} \frac{(2a+t\gamma-a\gamma^2-a\gamma)^2}{(1-\gamma^2)(4-\gamma^2)^2} & \text{if } j = 1 \\ \frac{(2a+t\gamma^2-a\gamma^2-a\gamma-2t)^2}{(1-\gamma^2)(4-\gamma^2)^2} & \text{if } j = 2, \end{cases} \tag{3..3}$$

where $p_{1j}(\gamma, t)$, $q_{1j}(\gamma, t)$ and $\pi_{1j}(\gamma, t)$ denote the equilibrium prices, quantities and profits for firm 1 respectively. The definitions of $p_{2j}(\gamma, t)$, $q_{2j}(\gamma, t)$ and $\pi_{2j}(\gamma, t)$ are analogous where for firm 2, $c_{2j} = c + t$ if $j = 1$, and $c_{2j} = c$ if $j = 2$.

Define

$$\pi_i(\gamma, t) = \pi_{i1}(\gamma, t) + \pi_{i2}(\gamma, t). \tag{3..4}$$

Firm i's Stage 2 equilibrium profits are given by

$$\pi_i(\gamma, t) = \begin{cases} \pi_i(\gamma_0 + x, t) & \text{if firms collaborate} \\ \pi_i(\gamma_0, t) & \text{if firms do not collaborate.} \end{cases} \tag{3..5}$$

We make two assumptions on fixed costs and trade costs throughout the paper to ensure that each firm sells a strictly positive amount in both markets under both subgames.

Assumption 1: $F < \min\{\pi_i(\gamma_0, t), 2\pi_i(\gamma_0 + x, t)\} = F'$.

This assumption consists of two parts. The first part, $F < \pi_i(\gamma_0, t)$, ensures that fixed cost is low enough so that firms produce in the equilibrium of the non-collaboration subgame (net profits will be positive). The second part, $F < 2\pi_i(\gamma_0 + x, t)$, implies that fixed cost is low enough so that each firm produces in the equilibrium of the collaboration subgame.[8] This assmption ensures that each firm sells in both markets in the equilibrium of both subgames.
Assumption 2: $t < \min(\bar{t}(\gamma_0), \bar{t}(\gamma_0 + x))$ where $\bar{t}(\gamma) = \frac{a(\gamma+2)(1-\gamma)}{(2-\gamma^2)}$.

If trade cost is large, firms do not export and each firm becomes a monopolist in its domestic market. Assumption 2 ensures that trade cost is low enough so that firms choose to export and there is duopoly competition in both markets.

3.1. When do firms collaborate?

Under collaboration, firm i's overall profits are $\pi_i(\gamma_0 + x, t) - \frac{F}{2}$, while in the absence of collaboration firm i's overall profits are $\pi_i(\gamma_0, t) - F$. Firms collaborate if

$$\pi_i(\gamma_0 + x, t) - \frac{F}{2} \geq \pi_i(\gamma_0, t) - F. \tag{3..6}$$

Now we record the effect of a change in the degree of product distinctiveness (x) on firms' profits.

Lemma 1 *There exists a value $\tilde{t} \in (0, \bar{t})$ such that profits decrease with loss in product distinctiveness ($\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} < 0$) for all $t \in (0, \tilde{t})$ and profits increase with loss in product distinctiveness ($\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} > 0$) for all $t \in (\tilde{t}, \bar{t})$.*

As x increases, the products become less distinct, intensifying competition between the firms, which leads to lower profits. If $t = 0$, this is the only effect and as a result $\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} < 0$ for $t = 0$. For $t > 0$, there is a second effect which arises because of the presence of cost asymmetry. Since firms are located in different countries, trade costs give the domestic firm a "cost advantage" over its foreign rivals in its own market. This cost advantage is large if t is large. The intensified product market competition increases firm i's domestic market share but reduces its foreign market share. Thus, an intensification of product market competition unambiguously reduces firm i's profits in the foreign market, but its overall effect depends on the strength of the increase in domestic profits and reduction in profits in the foreign market. We find that when t (cost asymmetry) is large enough, the former effect dominates the latter and overall profits increases. Hence $\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} > 0$ for all $t \in (\tilde{t}, \bar{t})$. The authors effect is similar to the one pointed out in Aghion and Schankerman (2004). They showed that an increase in product substitutability can increase the profits of an efficient firm.

Using Lemma 1 it is easy to establish the following result:

Proposition 1 *For $t \in (\tilde{t}, \bar{t})$, firms 1 and 2 choose to collaborate at stage 1 for all $x \in (0, 1-\gamma_0)$.*

Recall that firms collaborate if and only if $\pi_i(\gamma_0 + x, t) - \frac{F}{2} \geq \pi_i(\gamma_0, t) - F$. From Lemma 1 we know that for $t > \tilde{t}$, firms actually gain from loss in product distinctiveness, i.e., $\pi_i(\gamma_0 +$

[8] Here, $F < 2\pi_i$ is used as two firms share the fixed costs of F. Since profits are symmetric, total net profits have to be positive for the firms to produce.

$x, t) > \pi_i(\gamma_0, t)$. In addition, the fixed cost is lower from collaboration (i.e., $\frac{F}{2} < F$). Thus, $\pi_i(\gamma_0 + x, t) - \frac{F}{2}$ is always greater than $\pi_i(\gamma_0, t) - F$, which implies Proposition 1.

Now let us turn to $t \in (0, \tilde{t})$. From Lemma 1, we know that if $t < \tilde{t}$, firms lose from reduction in product distinctiveness. That is, $\pi_i(\gamma_0 + x, t) < \pi_i(\gamma_0, t)$. The loss from collaboration function, $L(\gamma_0, x, t)$, is defined as follows:

$$L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t). \qquad (3..7)$$

Since $\pi_i(\gamma_0 + x, t)$ is decreasing in x when t is small, it immediately follows that:

Lemma 2 *For $t \in (0, \tilde{t})$, the loss from collaboration function is increasing in x. That is, $\frac{dL(\gamma_0, x, t)}{dx} > 0$ for all $t \in (0, \tilde{t})$.*

Using Lemma 1 and the fact that firms 1 and 2 choose to collaborate if and only if the loss in profits from collaboration is less than the gain in cost savings (i.e., $L(\gamma_0, x, t) \leq \frac{F}{2}$), we have Proposition 2.

The proposition identifies the condition where collaboration occurs in equilibrium.

Proposition 2 *For all $t \in (0, \tilde{t})$, there exists a function $x^*(t)$ such that firms 1 and 2 collaborate if and only if $x \leq x^*(t)$, where $x^*(t) \in (0, 1 - \gamma_0)$.*

Lemma 2 tells us that each firm i's post-collaboration profits are decreasing in x. When the loss in product distinctiveness is zero, we have $L(\gamma_0, 0, t) \leq \frac{F}{2}$. Then, since the advantage of the collaboration (fixed cost saving) is not affected by x, firms 1 and 2 choose to collaborate when x is relatively small, as stated in Proposition 2.

Figure 1 is an illustration of the gains and losses from collaboration. Note that $x^*(t)$ depicts the value of the loss in product distinctiveness for which firms are indifferent between collaboration and non-collaboration. For all $x \leq x^*(t)$, the cost savings are greater than the loss in profits and hence firms collaborate. On the other hand, for all $x > x^*(t)$, loss in profits is greater than cost savings and firms do not collaborate.

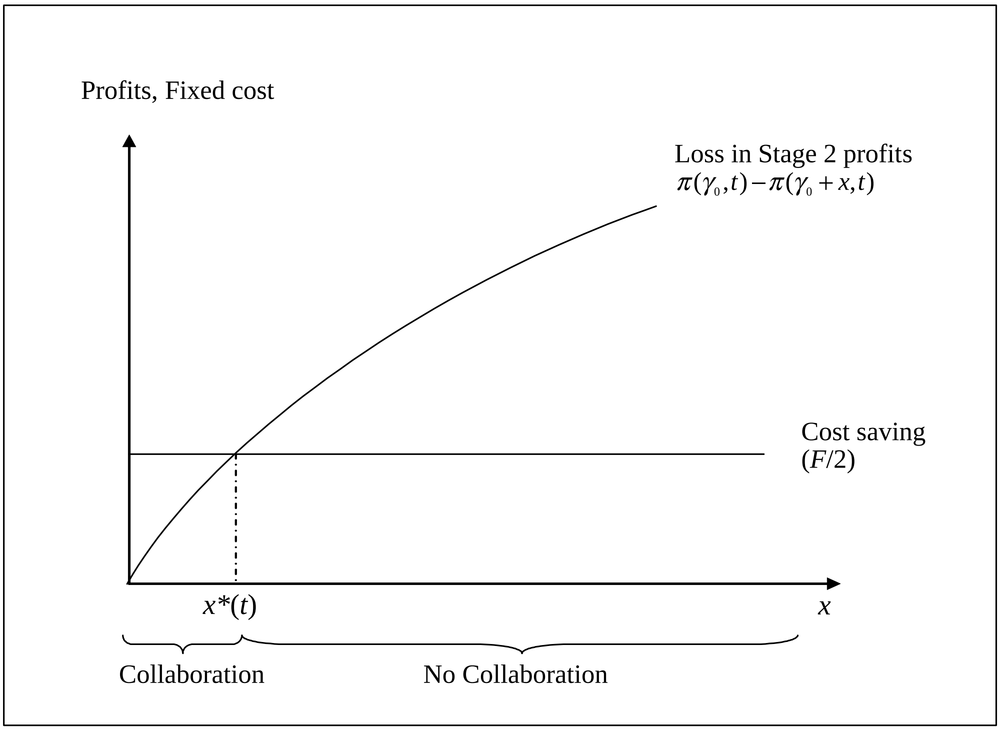

Figure 1: Collaboration − Cost savings versus loss in profits

3.2. How does trade cost affect collaboration?

From the previous subsection, we know that firms always collaborate when $t \in (\tilde{t}, \bar{t})$. Hence, we focus on $t \in (0, \tilde{t})$. Before we turn to a change in t affects collaboration, we look at how a change in trade costs affects profits.

Recall that $\pi_i(\gamma, t) = \pi_{ii}(\gamma, t) + \pi_{ij}(\gamma, t)$, where $i \neq j$. As t increases, protection is higher for firms in their domestic market. As a result, $\pi_{ii}(\gamma, t)$ increases. But at the same time $\pi_{ij}(\gamma, t)$ declines. Thus, the net effect is not clear cut. For $\gamma = 1$, Brander and Krugman (1983) showed that as t increases, $\pi_i(\gamma, t)$ declines when t is small and $\pi_i(\gamma, t)$ increases when t is large. We find that the same holds for other values of γ as well.

Now we turn to investigating the impact of an increase in trade cost on firms' collaboration decision. Though increasing t can increase or decrease $\pi_i(\gamma, t)$, we find that $L(\gamma_0, x, t) \equiv \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t)$ is strictly decreasing in t.

Lemma 3 *For all $x \in (0, 1 - \gamma_0)$, $L(\gamma_0, x, t)$ is strictly decreasing in t for all $t \in (0, \tilde{t})$.*

Since the loss from collaboration function represents the differences between firm i's profits in the non-collaboration and collaboration subgames, the net effect of a change in trade costs depends on how profits in each subgame reacts to a change in t. In both subgames, an increase in trade costs increases firm i's domestic profits while reducing its foreign profits. Although the effect of an increase in trade costs on profits in each subgame is ambiguous, we find that the loss from collaboration function is decreasing in t.

By definition, we find that $\frac{dL(\gamma_0,x,t)}{dt} = -\int_{\gamma_0}^{\gamma_0+x} \frac{\partial^2 \pi_i(\gamma,t)}{\partial\gamma\partial t} d\gamma$. From Lemma 1 we know that $\frac{\partial \pi_i(\gamma,t)}{\partial\gamma} < 0$. We find that as t increases, $\left|\frac{\partial \pi_i(\gamma,t)}{\partial\gamma}\right|$ declines. That is, as trade costs increase, the loss in profits from reduced distinctiveness is lower. This in turn implies that $\frac{dL(\gamma_0,x,t)}{dt} < 0$. Using Lemma 3 we can establish the following:

Proposition 3 *The threshold for collaboration increases as trade costs increase. More precisely, $x^*(t)$ increases as t increases for all $t \in (0, \tilde{t})$.*

From Proposition 2, we know that there exists a threshold $x^*(t)$ such that firms collaborate if $x \leq x^*(t)$, that is, the amount of loss in product distinctiveness that results from collaboration is lower than the threshold value. Proposition 3 says that the threshold is increasing in t. The intuition is as follows: an increase in t reduces competition between firms in both countries and firms can therefore afford to withstand greater reduction in product distinctiveness from collaboration in order to take advantage of the fixed cost saving.[9]

3.3. Trade cost and consumer welfare

In this section we investigate the effects of trade liberalisation on consumers in the presence of the possbility of competitor collaboration. In a standard oligopolistic trade model (e.g., Brander and Krugman (1983)), an increase in trade costs raises prices, which hurts the consumers. This effect is present in our framework as well. Given the expressions for $p_{ij}(\gamma,t)$ and $q_{ij}(\gamma,t)$ from (3..1) and (3..2), we find that consumer surplus is given by:

$$\begin{aligned} CS_j &= U(q_{1j}, q_{2j}) - p_{1j}(\gamma,t)q_{2j}(\gamma,t) - p_{2j}(\gamma,t)q_{2j}(\gamma,t) \\ &= a(q_{1j}+q_{2j}) - \frac{(q_{1j}^2 + 2\gamma q_{1j}q_{2j} + q_{2j}^2)}{2} \\ &\quad -p_{1j}(\gamma,t)q_{2j}(\gamma,t) - p_{2j}(\gamma,t)q_{2j}(\gamma,t). \end{aligned} \tag{3..8}$$

Let $CS_j(\gamma,t)$ denote the consumer surplus of the representative consumer in country j. Substituting $p_{1j}(\gamma,t) = a - q_{1j} - \gamma q_{2j}$ and $p_{2j} = a - q_{2j} - \gamma q_{1j}$ yields

$$CS_j = \frac{(q_{1j}^2 + 2\gamma q_{1j}q_{2j} + q_{2j}^2)}{2}. \tag{3..9}$$

Now we can substitute $q_{11}(\gamma,t)$ and $q_{21}(\gamma,t)$ from (3..2) and write

$$CS_1(\gamma,t) \equiv \frac{(4-3\gamma^2)}{2(1-\gamma^2)(4-\gamma^2)^2}t^2 - \frac{a}{(\gamma+1)(2-\gamma)^2}t + \frac{a^2}{(\gamma+1)(2-\gamma)^2}, \tag{3..10}$$

which is analogous to $CS_2(\gamma,t)$.

Lemma 4 *$CS_j(\gamma,t)$ is strictly decreasing in t.*

[9] Higher reduction in production distinctiveness increases competition. This offsets the reduction in competition through higher trade costs.

The intuition for Lemma 4 is simple. An increase in trade costs reduces competition between firms, which raises prices and lowers quantities. This in turn reduces consumer surplus.

Next we investigate the effect of the degree of product distinctiveness (γ) on consumer surplus ($CS_j(\gamma, t)$).

Lemma 5 *$CS_j(\gamma, t)$ is strictly increasing in γ.*

Note that an increase in γ has two effects. First, it reduces the distinctiveness between products, which lowers consumers' utility. The degree of product differentiation declines and so does the utility of the representative consumer who prefers product variety. Second, an increase in γ increases competition among firms, which benefits consumers through lower equilibrium prices. Lemma 5 tells us that the benefit from lower prices outweighs the loss from reduced product variety. The lemma can also be used to compare welfare between the two subgames in Stage 2. Since products are less differentiated in the collaboration subgame, $\gamma_0 < \gamma_0 + x$, and by Lemma 5 it follows that consumer surplus in the collaboration subgame is always higher than in the non-collaboration subgame. That is, $CS_j(\gamma_0, t) < CS_j(\gamma_0 + x, t)$.

Let $CS_j^*(t)$ be the equilibrium consumer surplus of the entire game for any given $t \in (0, \bar{t})$. If $x \leq x^*(t)$, firms collaborate, $\gamma = \gamma_0 + x$, and accordingly $CS_j^*(t) = CS_j(\gamma_0 + x, t)$. However, if $x > x^*(t)$, firms do not collaborate, which implies $\gamma = \gamma_0$, and accordingly $CS_j^*(t) = CS_j(\gamma_0, t)$. Thus we can write:

$$CS_j^*(t) = \begin{cases} CS_j(\gamma_0 + x, t) \text{ if } x \leq x^*(t) \\ CS_j(\gamma_0, t) \text{ if } x > x^*(t). \end{cases} \tag{3..11}$$

Thus, the equilibrium consumer surplus is the consumer surplus of the collaboration subgame when $x \leq x^*(t)$, and the consumer surplus of the non-collaboration subgame when $x > x^*(t)$.

Next we investigate the impact of an increase in trade costs on consumer surplus. Suppose t increases from t_0 to t_1, where $0 < t_0 < t_1 < \bar{t}$. To cover all the possibilities of a change in t, we present our analysis in two separate propositions: Proposition 4 considers the case of $x \notin (x^*(t_0), x^*(t_1)]$. Proposition 5 considers the effect of trade costs when $x \in (x^*(t_0), x^*(t_1)]$.

Proposition 4 *An increase in trade costs reduces consumer surplus as long as firms' collaboration decision is not affected. More precisely, for all t_0 and t_1 satisfying $0 < t_0 < t_1 < \tilde{t}$, we have that $CS_j^*(t_0) > CS_j^*(t_1)$ for all $x \notin (x^*(t_0), x^*(t_1)]$.*

The results presented in this proposition cover two domains of x. The first is the domain of x where the loss in product distinctiveness is small, i.e., $x \in (0, x^*(t_0)]$. The second is the domain of x where the loss in product distinctiveness is large, i.e., $x \in (x^*(t_1), 1 - \gamma_0)$.

From Proposition 3, if $x \leq x^*(t_0)$, then $x < x^*(t_1)$ holds as well. This implies that firms collaborate for $t = t_0$ and $t = t_1$. Hence, for $x \leq x^*(t_0)$, we have $\gamma = \gamma_0 + x$ for both $t = t_0$ and $t = t_1$. Thus, the degree of product distinctiveness is the same for both values of t. From Lemma 4, we know that for a given value of product distinctiveness γ, $CS_j(\gamma, t)$ declines as t increases. This implies that consumer surplus is lower for $t = t_1$.

From Proposition 3, if $x > x^*(t_1)$, then $x > x^*(t_0)$ holds as well. This implies that firms do not collaborate for $t = t_1$ and $t = t_0$. For $x > x^*(t_1)$, we have $\gamma = \gamma_0$ for both $t = t_1$ and $t = t_0$. Thus, the degree of product distinctiveness is the same for both values of t. From Lemma 4, we know that for a given value of product distinctiveness γ, $CS_j(\gamma, t)$ declines as t increases. This implies that consumer surplus is lower for $t = t_1$.

The next proposition shows that an increase in t can actually increase consumer surplus by switching the collaboration decision.

Proposition 5 *Consumer surplus can increase with an increase in trade costs. More precisely, for any $t_0 \in (0, \tilde{t})$, there exists $t_1 \in (t_0, \tilde{t})$ and $\tilde{x} \in (x^*(t_0), x^*(t_1)]$ such that $CS_j^*(t_0) < CS_j^*(t_1)$ for all $x \in (\tilde{x}, x^*(t_1)]$.*

From Proposition 3 we get that when the loss in product distinctiveness from collaboration is intermediate, i.e., $x \in (x^*(t_0), x^*(t_1)]$, an increase in trade costs from t_0 to t_1 induces firms to switch from non-collaboration to collaboration in Stage 1. The impact of this change on equilibrium consumer surplus is two fold. First, from Lemma 4 we get that a higher level of trade costs weakens competition between firms, raises prices, lowers quantities and reduces welfare. Second, because higher trade costs induce firms to collaborate, Lemma 5 implies that more product homogeneity intensifies competition between firms, lowers prices, increases quantities and increases welfare. Here, the two effects discussed in Lemma 4 work in opposite directions.

The net effect on equilibrium consumer surplus depends on the magnitude of these two effects. This proposition tells us that there exists a value $x \in (x^*(t_0), x^*(t_1))$ such that consumer surplus is higher as a result of higher trade costs.

A standard result in the trade literature is that an increase in t lowers consumer surplus. However, in the presence of this possibility of collaboration, we find that result does not necessarily hold. That is, an increase in trade costs can lead to improved consumer surplus.

Figure 2 illustrates the possibility of an increase in consumer surplus following an increase in trade costs. After an increase in trade costs from t_0 to t_1 such that $0 < t_0 < t_1 < \tilde{t}$, the range of x where firms collaborate increases from $x \in (0, x^*(t_0)]$ to $x \in (0, x^*(t_1)]$. Moreover, firms switch collaboration decision in Stage 1 if $x \in (x^*(t_0), x^*(t_1)]$. If $x \leq x^*(t_0)$ or $x > x^*(t_1)$, then consumer surplus cannot increase with an increase in trade costs. On the other hand, if $x \in (x^*(t_0), x^*(t_1)]$, then an increase in trade costs can lead to higher consumer surplus.

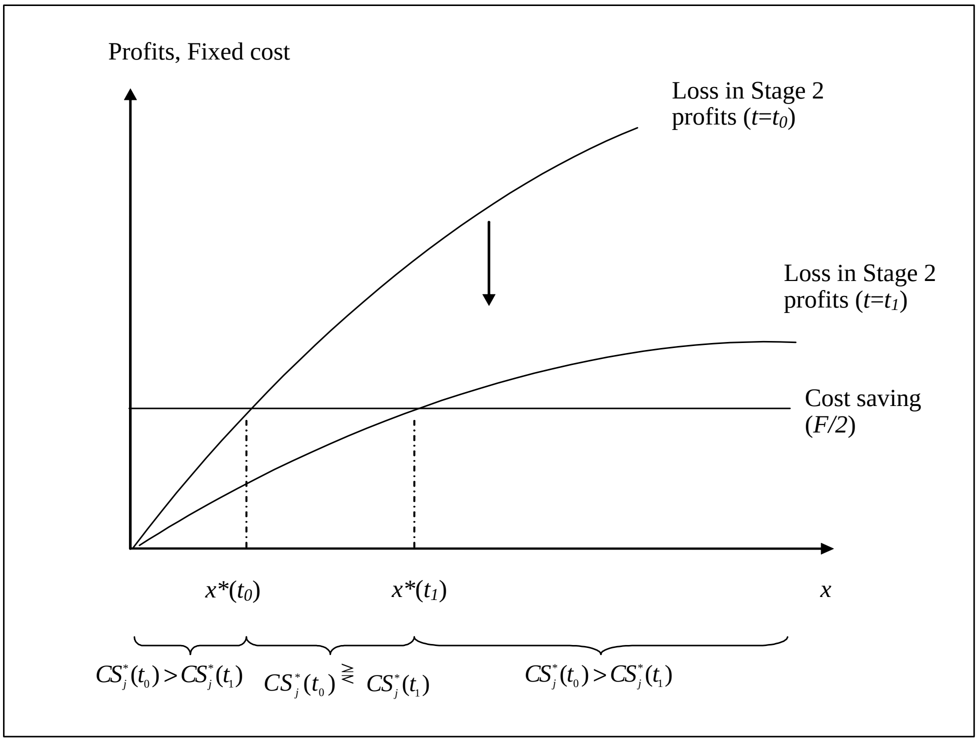

Figure 2: Change in loss function due to increase in trade costs

4. The Collaboration Game with a Location Choice

In this section, we analysed the competitor collaboration game in a standard international trade setting where firms are located in different countries (as discussed in Brander and Krugman, 1983). In this section we introduce the possibility of co-location (i.e., both firms are located in the same country). With the possibility of collaboration, firms can choose to be co-located for several reasons, some of which are discussed below.

First, collaborators choose to be co-located when they jointly invest in infrastructures or key assets. In a production collaboration, participating firms are often required to jointly build factories and/or invest in machinery in order to combine complementary technologies, know-how, and other assets to produce a good more efficiently or to produce a good that no one participant alone could produce. For example, in the LCD industry, Hitachi, Toshiba and Matsushita jointly established a company to manufacture LCD panels for flat panel TVs. The jointly established manufacturing facility in Mobara, Japan, provided the three companies with LCD panels for each company's LCD TVs (Kang and Sakai, 2000). On the other hand, S-LCD−a collaboration company formed by Samsung and Sony−has an LCD manufacturing facility in South Korea that produces LCD screens for both Samsung and Sony.[10] In the automobile industry, Toyota and GM established New United Motor Manufacturing Inc. (NUMMI) in

[10] http://news.com.com/Japanese+makers+forge+1+billion+LCD+alliance/2100-1041_3-5331665.html, visited Feb 28, 2008.

1984. A shuttered GM plant is used to build both Toyotas and GM cars using the same unionised work force, production line and Toyota Production System (TPS). This is one of the longest running known competitor collaborations.[11]

Second, collaborators choose to be located in the same country to benefit from knowledge spillovers. Knowledge spillover is natural in both R&D and production collaborations. In an R&D collaboration, firms benefit from spillovers as their engineers share their know-how, resources and experience to develop new or improved goods or production processes more efficiently and move into technological areas beyond their national reach. Likewise, in a production collaboration, firms share their learning and know-how of their production processes and benefit from each other's proprietary knowledge, economies of scale and scope. Hamel (1991, p. 86) suggests that collaborators also benefit from each other by "internalizing a partner's skill". In an unsuccessful alliance, the party which aggressively learns as much as possible benefits more than its partner even if the alliance collapses, given that both have made an equal investment. The most attractive resources to internalise are cutting edge technology and management techniques. Moreover, Draper (1990) points out that by collaborating, firms could be in the lower part of the learning curve when spillovers and information flows from collaborations are local.

Third, collaborators choose to be co-located to save on communication costs. Firms often incur communication costs when they collaborate in order to transfer knowledge and achieve spillovers. This cost includes the cost of voice and/or data communications between firms during the R&D or production stage. When firms are located in different countries, they may find that conveying key findings or knowledge might be too costly since engineers from the collaborating firms are required to work together closely in the product development stage. If communication is extremely costly, the only way firms can collaborate is to be located in the same country even if they do not engage in joint investment in infrastructure. For example, in 2001 Toshiba and Sony saved on communication costs by transferring their engineers to work at Toshiba's research centre in Shinsugita, Yokohama, near Tokyo while developing the 90-nanometer and 65-nanometer process nodes DRAM structure.[12]

In the real world, firms put as much emphasis on choosing the right location as on deciding whether to collaborate with their competitors. Given the importance of firms' strategic location choice, we present a theoretical framework incorporating firms' location decision and explore the economic and welfare implications of competitor collaboration in an international context.

4.1. The Model

In this extension to the original model, the environment is the same as in the original model analysed in the previous section, except for location choice. We incorporate a location decision node before Stage 1, which we refer to as Stage 0. We consider the three-stage subgame described below.

Stage 0 [Location decision]: Firms jointly decide whether to locate in the same or different countries. Each firm sets up one plant and uses it to serve both its domestic and foreign markets. For simplicity, we assume that firms locate in country 1 if they choose to be in the same country.[13]

[11] http://www.industryweek.com/readarticle.aspx?articleID=10164, visited February 28, 2008.

[12] http://www.eetimes.com/story/OEG20030117S0029, visited March 10, 2007.

[13] By symmetry of the model, the equilibria prices, quantities, product and welfare will be the same if both firms choose to be located in country 2.

Stage 1 [Collaboration decision]: In this stage, firms jointly decide whether or not to collaborate with their rivals to save on fixed costs. The trade-off is the same as that described in Stage 1 of the previous game (see Section 2.).
Stage 2 [Product market competition]: Identical to Stage 2 in the original model; firms compete in Bertrand fashion.

4.2. Analysis

We solve the equilibrium for the game using backward induction. First we start with Stage 2 and consider the subgame where both firms are located in the same country. Hereafter we refer to this subgame as S subgame.

In Stage 2, firm $i(=1,2)$ chooses p_{ij} to maximise its profits from selling in country 1 and 2. If both firms locate in country 1, the maximisation problem (introduced in the previous section) leads to

$$p_{ij}^S(\gamma,t) = \begin{cases} \frac{a(1-\gamma)}{(2-\gamma)} & \text{if } j=1 \\ \frac{(a+t-a\gamma)}{(2-\gamma)} & \text{if } j=2, \end{cases} \tag{4..1}$$

$$q_{ij}^S(\gamma,t) = \begin{cases} \frac{a}{(\gamma+1)(2-\gamma)} & \text{if } j=1 \\ \frac{(a-t)}{(\gamma+1)(2-\gamma)} & \text{if } j=2, \end{cases} \tag{4..2}$$

and

$$\pi_{ij}^S(\gamma,t) = \begin{cases} \frac{a^2(1-\gamma)}{(\gamma+1)(2-\gamma)^2} & \text{if } j=1 \\ \frac{(a-t)^2(1-\gamma)}{(\gamma+1)(2-\gamma)^2} & \text{if } j=2, \end{cases} \tag{4..3}$$

where the superscript S denotes the outcome from the same location subgame. Let $\pi_i^S(\gamma,t)$ denote the total profits of firm i. Then,

$$\pi_i^S(\gamma,t) = \sum_{j=1,2} \pi_{ij}^S(\gamma,t). \tag{4..4}$$

Let $\pi_i^D(\gamma,t)$ denote the total profits of firm i from being located in different countries. The function $\pi_i^D(\gamma,t)$ is the same as $\pi_i(\gamma,t)$ reported in the previous section.

Without the possibility of collaboration, firms would prefer to be located in different countries in order to benefit from trade protection. By being located apart, each firm has more market power in its domestic market because of trade barriers. Trade costs give the domestic firm a cost advantage over its foreign rival and dampen the intensity of competition between firms.

Lemma 6 *For a given γ, firms always prefer to be located in different countries. That is, for a given $\gamma \in (0,1)$, $\pi_i^S(\gamma,t) < \pi_i^D(\gamma,t)$.*

Collaboration requires co-ordination of several activities. We assume that co-ordination is extremely costly if the firms are in two different countries. To make this stark, we assume that co-ordination is not feasible and hence collaboration can not occur if firms are located in different countries. This assumption, together with Lemma 6, implies that in the overall equilibrium of the game, only two things are possible. Firms can choose the same location (S) and collaborate or they can choose different locations (D) and not collaborate. That is, if firms choose S, it must be that $\gamma = \gamma_0 + x$ and $\pi_i^S(\gamma, t) = \pi_i^S(\gamma_0 + x, t)$. If firms choose D, then $\gamma = \gamma_0$ and $\pi_i^D(\gamma, t) = \pi_i^D(\gamma_0, t)$.

In this game, firm i's equilibrium profit is given by

$$\pi_i(\gamma, t) = \begin{cases} \pi_i^S(\gamma_0 + x, t) & \text{if firms collaborate} \\ \pi_i^D(\gamma_0, t) & \text{if firms do not collaborate.} \end{cases} \tag{4..5}$$

Now define the loss function as follows:

$$\tilde{L}(\gamma_0, x, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t). \tag{4..6}$$

A crucial difference from the previous analysis is that when $x = 0$, the loss from collaboration is strictly positive since $\tilde{L}(\gamma_0, x, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t) > 0$ (from Lemma 6).

To make sure that firms do collaborate when $x = 0$, we make the following assumption:
Assumption 3: $\frac{F}{2} > \tilde{L}(\gamma_0, 0, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0, t)$.
We continue to invoke Assumptions 1 and 2 from the previous section.

4.2.1. When do firms collaborate?

During collaboration, firm i's overall profits are

$$\pi_i^S(\gamma_0 + x, t) - \frac{F}{2}, \tag{4..7}$$

while in the absence of collaboration firm i's overall profits are

$$\pi_i^D(\gamma_0, t) - F. \tag{4..8}$$

Firms collaborate if $\pi_i^S(\gamma_0 + x, t) - \frac{F}{2} \geq \pi_i^D(\gamma_0, t) - F$ or equivalently if

$$\tilde{L}(\gamma_0, x, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t) \leq \frac{F}{2}. \tag{4..9}$$

Lemma 7 *For all $t \in (0, \bar{t})$, the loss from collaboration is increasing in x. That is $\frac{d\tilde{L}(\gamma_0, x, t)}{dx} > 0$ for all $t \in (0, \bar{t})$.*

Since $\frac{d\tilde{L}(\gamma_0, x, t)}{dx} = -\frac{d\pi_i^S(\gamma_0 + x, t)}{dx} < 0$ for all $t \in (0, \bar{t})$, $\gamma_0 \in (0, 1)$ and $x \in (0, 1 - \gamma_0)$, the loss from collaboration increases with x. Proposition 6 identifies the condition such that $\tilde{L}(\gamma_0, x, t) \leq \frac{F}{2}$, i.e., collaboration occurs in equilibrium.

Proposition 6 *For all $t \in (0, \bar{t})$, there exists a function $x^*(t)$ such that firms 1 and 2 collaborate if and only if $x \leq x^*(t)$, where $x \in (0, 1 - \gamma_0)$.*

The reasoning is analogous to Proposition 2 and follows from Lemma 7 and Assumption 3. The result follows from comparing the costs and benefits of collaboration and noting that while benefit is independent of x, the cost increases with x.

4.2.2. How does trade cost affect collaboration?

The effect of an increase in trade cost on collaboration is not as clear cut as in Proposition 3. Note that firms collaborate if and only if $x \leq x^*(t)$ where $x^*(t)$ satisfies the following:

$$\tilde{L}(\gamma_0, x^*(t), t) = \frac{F}{2}. \tag{4..10}$$

Totally differentiating (4..10) and rearranging it we get:

$$\frac{dx^*(t)}{dt} = -\left.\frac{\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}}{\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial x}}\right|_{x=x^*(t)}. \tag{4..11}$$

From Lemma 7, we know that $\tilde{L}(\gamma_0, x, t)$ is increasing in x for all $t \in (0, \bar{t})$. Hence, the effect of trade cost on $x^*(t)$ depends on the sign of $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}$, where $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t} = \frac{\partial \pi_i^D(\gamma_0,t)}{\partial t} - \frac{\partial \pi_i^S(\gamma_0+x,t)}{\partial t}$.

Lemma 8 *Loss in profits from collaboration can increase with an increase in trade cost if the loss in product distinctiveness due to collaboration is small. More precisely, for all $t \in (0, \bar{t})$, there exists $\hat{x}(\gamma_0, t) \in (0, 1-\gamma_0)$ such that $\tilde{L}(\gamma_0, x, t)$ is increasing in t if and only if $x < \hat{x}(\gamma_0, t)$.*

Recall in the previous section that the loss from collaboration was always decreasing in t. Here, as Lemma 8 suggests, that is not always the case.

Typically, an increase in t has two effects: market size effect and competition effect. An increase in t lowers total market size which lowers profits. On the other hand, it raises protection for firms in domestic markets and raises profits. Given that both firms are located in the same country when they collaborate, the competition effect is absent. Market size declines with an increase in t, hence $\frac{\partial \pi_i^S(\gamma_0+x,t)}{\partial t} < 0$. However, both the market size effect and competition effect are present when firms do not collaborate and are located in different countries. This creates the possibility for $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t} > 0$.

Proposition 7 *Depending on parameterisations, an increase in trade cost could encourage or discourage collaboration. More precisely, for all $t \in (0, \bar{t})$, there exists $\hat{\gamma}_0 \in (0, 1)$ such that:*

(i) if $\gamma_0 > \hat{\gamma}_0$, we have that $\frac{dx^*(t)}{dt} < 0$,

(ii) if $\gamma_0 < \hat{\gamma}_0$, there exists $\hat{F}(\gamma_0, t)$ such that $\frac{dx^*(t)}{dt} < (>) 0$ if $F < (>) \hat{F}(\gamma_0, t)$.

As Lemma 8 suggests, for a reduction in t to encourage collaboration the loss in product distinctiveness has to be low (i.e., $x^*(t)$ is small). This implies that the fixed cost saving has to be small as well, which explains the upper limit of F.

The differences between propositions 3.3 and 4.3 are as follows. If firms can collaborate without being in the same country, then an increase in trade cost encourages collaboration. However, if collaboration requires co-location, an increase in t could discourage collaboration. An implication is that in industries where collaboration requires proximity in terms of physical location, trade liberalisation might prompt collaboration.

4.2.3. Trade cost and consumer welfare

This section investigates the effects of a change in trade costs on consumer surplus. Unlike in the standard model, here consumer surplus are not necessarily equal in two countries. In particular, when firms collaborate and are both located in country 1, consumers of country 1 are better off compared to consumers of country 2 because there is an additional export cost of $t > 0$ per unit that firms face to serve country 2's market, which raise prices in country 2.

There are two major findings in this subsection. First, as in the previous section we find that contrary to the standard intuition that trade costs have adverse effects on consumers, higher trade costs could benefit some consumers with the possibility of collaboration and increase aggregate consumer surplus (Proposition 10). Moreover, we find that for any given trade cost, consumers may be better off if firms do not collaborate (Proposition 9).

First, we compute consumer surplus for countries 1 and 2. Proceeding analogously to the standard model, we find:

$$CS_1^S(\gamma, t) \equiv \frac{a^2}{(1+\gamma)(2-\gamma)^2}, \tag{4..12}$$

$$CS_2^S(\gamma, t) \equiv \frac{(a-t)^2}{(1+\gamma)(2-\gamma)^2} \tag{4..13}$$

where the superscript S denotes the same location subgame.

Define $CS^S(\gamma, t)$ as the aggregate consumer surplus of the representative consumers in country 1 and 2 when firms are located in the same country. We have:

$$CS^S(\gamma, t) = CS_1^S(\gamma, t) + CS_2^S(\gamma, t).$$

Next we present the comparative static results of the aggregate consumer surplus when firms are co-located.

Lemma 9 *When firms collaborate the aggregate consumer surplus is decreasing in t and increasing in γ. That is,*
(i) $\frac{dCS^S(\gamma,t)}{dt} < 0$ *for all* $t \in (0, \bar{t})$,
(ii) $\frac{dCS^S(\gamma,t)}{d\gamma} > 0$ *for all* $\gamma \in (0, 1)$.

The findings in this Lemma are similar to the ones in Lemma 4 and Lemma 5. Nevertheless, the intuition is somewhat different. When firms are co-located (in country 1), the effect of an increase in trade cost on $CS_1^S(\gamma, t)$ and $CS_2^S(\gamma, t)$ is different.

Given that both firms are located in country 1, an increase in trade costs does not affect prices and quantities in country 1. Hence, $CS_1^S(\gamma, t)$ is not affected by a change in t. On the other hand, all prices increase in country 2 increase as trade costs increase. Hence, $CS_2^S(\gamma, t)$ declines with an increase in t in country 2. Thus, the overall aggregate consumer surplus declines, with increases in trade costs.

Analogous to Lemma 5, an increase in γ has two effects. First, it reduces the distinctiveness between products, which lowers consumers' utility. The degree of product differentiation declines and so does the utility of the representative consumer who prefers product variety. Second, an increase in γ increases competition among firms, which benefits consumers through lower equilibrium prices. Benefits due to lower prices outweigh the loss from reduced product variety.

Next we consider consumer surplus where firms are located in different countries. In this case, since the model is symmetric, $CS_1^D(\gamma,t) = CS_2^D(\gamma,t)$, where $CS_i^D(\gamma,t)$ is the same as in the standard model. Define

$$CS^D(\gamma,t) = CS_1^D(\gamma,t) + CS_2^D(\gamma,t). \tag{4..14}$$

As in Lemma 4, we find that $CS_i^D(\gamma,t)$ is increasing with t and decreasing with γ. The following proposition compares between $CS^D(\gamma,t)$ and $CS^S(\gamma,t)$.

Proposition 8 *For a given γ, consumers always prefer firms to be located in different countries in Stage 0. We have $CS^S(\gamma,t) < CS^D(\gamma,t)$ for all $t \in (0,\bar{t})$ and $\gamma \in (0,1)$.*

We can write $CS^S(\gamma,t) - CS^D(\gamma,t)$ as follows:

$$CS^S(\gamma,t) - CS^D(\gamma,t) = CS_1^S(\gamma,t) - CS_1^D(\gamma,t) + CS_2^S(\gamma,t) - CS_2^D(\gamma,t). \tag{4..15}$$

In country 1, the effective unit cost for firms 1 and 2 is zero if they are co-located. If they are located in different countries, effective unit costs are 0 and t. Hence, prices are lower and outputs are higher in country 1 if they are co-located. Having two local producers means that domestic competition is more intense as trade costs have no impact on equilibrium prices and quantities. Thus, we have that $CS_1^S(\gamma,t) - CS_1^D(\gamma,t) > 0$.

In country 2, the effective unit cost for firms 1 and 2 is t if they are co-located. If they are located in different countries, effective costs are t and 0. Hence, prices are lower and output higher in country 2 if firms are located in different countries. We have that $CS_2^S(\gamma,t) - CS_2^D(\gamma,t) < 0$, implying that consumers in country 2 prefer to have one local producer than none.

At the aggregate level, the loss to consumers in country 2 from having no local producer outweighs the gain to consumers in country 1 from having two local producers. Hence, aggregate consumer surplus is higher if firms are located in different countries for a given γ. Using the standard continuity argument, we get the following:

Proposition 9 *For all $t \in (0,\bar{t})$, there exists $\check{x}(t)$ such that $CS^D(\gamma_0,t) > CS^S(\gamma_0 + x,t)$ if $x \leq \check{x}(t)$.*

Note that consumer surplus during collaboration is given by $CS^S(\gamma_0+x,t)$, whereas for non-collaboration it is given by $CS^D(\gamma_0,t)$. Then Proposition 9 follows from noting that $\lim_{x\to 0} CS^D(\gamma_0,t) - CS^S(\gamma_0+x,t) \simeq CS^D(\gamma_0,t) - CS^S(\gamma_0,t) > 0$ (from Proposition 8).

To investigate the effect of a change in trade costs on aggregate consumer surplus, first let us define $CS^*(t)$ as consumer surplus in the equilibrium of the overall game for a given t. We have that:

$$CS^*(t) = \begin{cases} CS^S(\gamma_0 + x,t) \text{ if } x \leq x^*(t) \\ CS^D(\gamma_0,t) \text{ if } x > x^*(t). \end{cases} \tag{4..16}$$

Next, we investigate the relationship between trade costs and consumer surplus in a collaboration game.

Proposition 10 (*i*) *There exist parameterisations such that an increase in trade costs could lead to a higher consumer surplus by encouraging collaboration.*

(*ii*) *There also exist parameterisations such that an increase in trade costs could lead to a higher consumer surplus by discouraging collaboration.*

From Proposition 7 we know that an increase in trade costs can either encourage or discourage collaboration. This proposition suggests that in both circumstances, an increase in trade costs can lead to a higher aggregate consumer surplus. In particular, we know that when $\gamma_0 < \hat{\gamma}_0$ and F is large, an increase in trade costs from t_0 to t_1 can lead firms to switch from non-collaboration to collaboration for $x \in (x^*(t_0), x^*(t_1)]$. Here, the underlying reason for consumer surplus increasing with an increase in trade costs is analogous to the one discussed in the previous section. An increase in trade costs induces firms to switch to co-location and collaboration when $x \in (x^*(t_0), x^*(t_1)]$. Collaboration lowers variety which hurts consumer surplus. However, in the presence of collaboration, competition becomes more intense, which raises consumer surplus. We find that there exists parameterisation such that the latter effect dominates the former.

For high γ_0 ($\gamma_0 > \hat{\gamma}_0$) or low F ($F < \hat{F}(\gamma, t)$), an increase in trade costs can induce firms to switch from collaboration to non-collaboration when $x \in [x^*(t_1), x^*(t_0))$. The fact that firms do not collaborate reduces aggregate consumer surplus because prices increase as a result of more product distinctiveness. Nevertheless, aggregate consumer surplus increases as firms switch to being located in different countries. We find that there exist parameterisations such that the latter effect dominates the former and aggregate consumer surplus increases in equilibrium.

5. Conclusion

The world has witnessed a phenomenal growth of cross-border alliances between competing firms in the last two decades. The existence of such collaborations is prominent in a number of industries including the automobile, pharmaceutical, semiconductor, liquid crystal display (LCD) and financial industries.

This paper considers collaboration in value creating activities (technology development, product design, manufacturing, marketing, distribution and services) where firms save on fixed costs at the expense of product distinctiveness. Building on Ghosh and Morita (2006), we develop a model of international collaboration where save costs but reduce product distinctiveness.

First, we characterise the conditions where collaboration takes place and show how firms' strategic decision are affected by trade costs. In the endogenous location choice model, we find that an increase in trade costs affects collaboration differently depending on whether collaboration requires co-location or not. Moreover, unlike the standard findings in trade models where an increase in trade costs lowers consumer surplus, we find that an increase in trade costs may result in higher consumer surplus with the possibility of collaboration. This result holds under both models studied in this part of the paper but the intuition is different for each. There are many policy implications of this result: if higer tariffs can encourage collaboration and improve welfare, the government has to be careful when considering trade liberalisation. It needs to consider the welfare effects trade liberalisation will have on its own country.

Our results capture the connection between firms' collaboration decisions and tariffs, which provides a new perspective on the welfare consequences of trade liberalisation. Our findings suggest that policy makers should carefully investigate the welfare consequences of a tariff reduction. If collaboration does not require co-location, a reduction in tariff rate may discourage collaboration and reduce consumer surplus. When collaboration does require co-location, we have shown that depending on the magnitude of fixed cost savings, a reduction in tariff may encourage or discourage collaboration. For both cases, consumer surplus may decrease as a result of trade liberalisation. In the case where collaboration requires co-location, consumers in the country where firms are located are better off than their foreign counterparts. Hence, policy makers should consider tax exemptions or export subsidies to encourage firms to be located in their country. Since lower trade costs encourage collaboration and hence co-location, a country wishing to raise its welfare could consider an increase in trade costs to encourage one firm to move there.

Several extensions of this model are possible. For example, instead of Bertrand, one can consider Cournot competition. Preliminary calculations suggest that the main results remain quantitatively unchanged under Cournot competition. Note that we have assumed that collaboration reduces fixed costs. An interesting extension worth investigating is the case of marginal cost savings. We leave the analysis of such arrangements for future research.

6. Appendix

A. Proof of Lemma 1: We have that $\left.\frac{\partial \pi_i(\gamma,t)}{\partial \gamma}\right|_{t=0} = -4a^2 \frac{(1-\gamma(1-\gamma))}{(\gamma+1)^2(2-\gamma)^3} < 0$ for all $\gamma \in (0,1)$. Since $\gamma_0 < \gamma_0 + x$, $\left.\frac{\partial \pi_i(\gamma,t)}{\partial \gamma}\right|_{t=0} < 0 \Rightarrow \left.\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x}\right|_{t=0} < 0$. At $t = \bar{t}$, we have $\left.\frac{\partial \pi_i(\gamma,t)}{\partial \gamma}\right|_{t=\bar{t}} = 2a^2\gamma(1-\gamma)\frac{\gamma+1}{(4-\gamma^2)(2-\gamma^2)^2} > 0$ for all $\gamma \in (0,1)$. This implies $\left.\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x}\right|_{t=\bar{t}} > 0$. The claim that there exists a unique $\tilde{t}$ such that $\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} < 0$ for all $t \in (0,\tilde{t})$ and $\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} > 0$ for all $t \in (\tilde{t},\bar{t})$ follows from noting that

$$\frac{\partial}{\partial t}\left(\frac{\partial \pi_i(\gamma,t)}{\partial \gamma}\right) = \frac{\partial^2 \pi_i(\gamma,t)}{\partial \gamma \partial t} = \frac{2}{(1-\gamma^2)^2(4-\gamma^2)^3}(At+B) > 0,$$

where $A = 2\gamma\left(12+2\gamma^4-\gamma^2\left(\gamma^4+7\right)\right) > 0$ and $B = 2a\left(1-\gamma+\gamma^2\right)(1-\gamma)^2(\gamma+2)^3 > 0$ for all $\gamma \in (0,1)$. *Q.E.D.*

B. Proof of Proposition 1: Recall from (3..7), $L(\gamma_0,x,t) = \pi_i(\gamma_0,t) - \pi_i(\gamma_0+x,t)$ where $\pi_i(\gamma_0,t) = \pi_{i1}(\gamma_0,t) + \pi_{i2}(\gamma_0,t)$ and $\pi_i(\gamma_0+x,t) = \pi_{i1}(\gamma_0+x,t) + \pi_{i2}(\gamma_0+x,t)$. Define

$$h(\gamma_0,x,t,F) \equiv \frac{F}{2} - L(\gamma_0,x,t).$$

Firms collaborate if $h(\gamma_0,x,t,F) \geq 0$. For $t \in (\tilde{t},\bar{t})$, $L(\gamma_0,x,t) < 0$ which in turn implies that $h(\gamma_0,x,t,F)$ is always strictly positive. *Q.E.D.*

C. Proof of Lemma 2: We have that $\frac{dL(\gamma_0,x,t)}{dx} = -\frac{\partial \pi_i(\gamma_0+x,t)}{\partial x} > 0$ where the inequality follows from applying Lemma 1. *Q.E.D.*

D. Proof of Proposition 2

Now note that $L(\gamma_0,0,t) = 0$. Consequently, $h(\gamma_0,0,t,F) = \frac{F}{2} > 0$. Now, from Lemma 1, for $t < \tilde{t}$ we have that $\frac{dh(\gamma_0,x,t,F)}{dx} = -\frac{dL(\gamma_0,x,t)}{dx} < 0$ for all $x \in (0,1-\gamma_0)$. Then either:
(i) $h(\gamma_0,x,t,F) > 0$ for all $x \in (0,1-\gamma_0)$ or
(ii) there exist $\tilde{x}(t) \in (0,1-\gamma_0)$ such that $h(\gamma_0,x,t,F) \geq 0$ if and only if $x \leq \tilde{x}(t)$.

It can be shown using Assumption 1 that (i) cannot hold. If (ii) holds, define $x^*(t) = \tilde{x}(t)$. *Q.E.D.*

E. Proof of Lemma 3: Differentiating $L(\gamma_0,x,t) = \pi_i(\gamma_0,t) - \pi_i(\gamma_0+x,t)$ with respect to t, we have that

$$\begin{aligned}
\frac{dL(\gamma_0,x,t)}{dt} &= \frac{\partial \pi_i(\gamma_0,t)}{\partial t} - \frac{\partial \pi_i(\gamma_0+x,t)}{\partial t} \\
&= \int_{\gamma_0+x}^{\gamma_0} \frac{\partial^2 \pi_i(\gamma,t)}{\partial \gamma \partial t} d\gamma \\
&= -\int_{\gamma_0}^{\gamma_0+x} \frac{\partial^2 \pi_i(\gamma,t)}{\partial \gamma \partial t} d\gamma \\
&< 0,
\end{aligned}$$

where the inequality follows from noting that $\frac{\partial^2 \pi_i(\gamma,t)}{\partial\gamma\partial t} > 0$ (see the proof in Lemma 1). *Q.E.D.*

F. Proof of Proposition 3: From the definition of $x^*(t)$ we have that

$$L(\gamma_0, x^*(t), t) - \frac{F}{2} = 0.$$

By applying the implicit function theorem and totally differentiating the above equation, we get

$$\frac{dx^*(t)}{dt} = -\left.\frac{\frac{\partial L(\gamma_0,x,t)}{\partial t}}{\frac{\partial L(\gamma_0,x,t)}{\partial x}}\right|_{x=x^*(t)}.$$

The claim then follows from noting that $\frac{dL(\gamma_0,x,t)}{dx} > 0$ (from Lemma 2), and $\frac{dL(\gamma_0,x,t)}{dt} < 0$ (from Lemma 3). *Q.E.D.*

G. Proof of Lemma 4: We have that

$$CS_j(\gamma, t) = \check{A}t^2 + \check{B}t + \check{C},$$

where $\check{A} = \frac{\left(4-3\gamma^2\right)}{2(1-\gamma^2)(4-\gamma^2)^2} > 0$, $\check{B} = -\frac{a}{(\gamma+1)(2-\gamma)^2} < 0$, and $\check{C} = \frac{a^2}{(\gamma+1)(2-\gamma)^2} > 0$ for all $\gamma \in (0,1)$. Differentiating $CS_j(\gamma, t)$ with respect to t, we have that

$$\frac{dCS_j(\gamma, t)}{dt} = 2\check{A}t + \check{B}.$$

Since $\check{A} > 0$ and $\check{B} < 0$, we have that $\check{A}t + \check{B} \le \check{A}\bar{t} + \check{B}$ for all $t \in (0, \bar{t})$. But $\check{A}\bar{t} + \check{B} = -\frac{a\gamma}{(4-\gamma^2)(2-\gamma^2)} < 0$. Hence, $\frac{dCS_j(\gamma,t)}{dt} < 0$ for all $t \in (0, \bar{t})$. *Q.E.D.*

H. Proof of Lemma 5: Differentiating $CS_j(\gamma, t)$ with respect to γ, we have that

$$\frac{dCS_j(\gamma, t)}{d\gamma} = \tilde{A}t^2 + \tilde{B}t + \tilde{C},$$

where $\tilde{A} = \frac{3\gamma\left(4+2\gamma^4-5\gamma^2\right)}{(1-\gamma^2)^2(4-\gamma^2)^3} > 0$, $\tilde{B} = -\frac{3a\gamma}{(1+\gamma)^2(2-\gamma)^3} < 0$, and $\tilde{C} = \frac{3a^2\gamma}{(1+\gamma)^2(2-\gamma)^3} > 0$ for all $\gamma \in (0, 1)$.

Since $\tilde{C} > 0$, $\left.\frac{dCS_j(\gamma,t)}{d\gamma}\right|_{t=0} > 0$. Furthermore, since $\tilde{B}^2 - 4\tilde{A}\tilde{C} = -9a^2\frac{\gamma^2}{(1-\gamma^2)^2(4-\gamma^2)^3} < 0$, there does not exist any real value of t for which $\frac{dCS_j(\gamma,t)}{d\gamma} < 0$. Hence, we have that $\frac{dCS_j(\gamma,t)}{d\gamma} > 0$ for all $t \in (0, \bar{t})$. *Q.E.D.*

I. Proof of Proposition 5: To prove Proposition 5, first we establish the following claim:
Claim 1: For all $t_0 \in (0, \tilde{t})$, there exists $\delta > 0$ and $x \in (0, 1 - \gamma_0)$ such that $CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta) > CS_j(\gamma_0, t_0)$.
Proof: Suppose that Claim 1 is not true, then there exists $t_0 \in (0, \tilde{t})$ such that for all $\delta > 0$ and $x \in (0, 1 - \gamma_0)$, $CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta) \le CS_j(\gamma_0, t_0)$. Then the following must hold:

$$\lim_{\delta\to 0} CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta) \le \lim_{\delta\to 0} CS_j(\gamma_0, t_0),$$

which in turn implies

$$CS_j(\gamma_0 + x^*(t_0), t_0) \le CS_j(\gamma_0, t_0).$$

Since $\frac{dCS_j(\gamma,t)}{d\gamma} > 0$ (Lemma 4), we cannot have that $CS_j(\gamma_0 + x^*(t_0), t_0) \le CS_j(\gamma_0, t_0)$. This completes the claim.

Pick $t_1 = t_0 + \delta$ and $x = x^*(t_0 + \delta)$. Then $CS_j^*(t_1) = CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta)$ and $CS_j^*(t_0) = CS_j(\gamma_0, t_0)$. Choose δ appropriately so that $CS_j^*(t_1) > CS_j^*(t_0)$. *Q.E.D.*

J. Proof of Lemma 6: For a given γ, $\pi_i^D(\gamma,t) - \pi_i^S(\gamma,t) = \frac{2t^2\gamma\left(2-\gamma^2\right)}{(1-\gamma^2)(4-\gamma^2)^2} > 0$ for all $\gamma \in (0,1)$. *Q.E.D.*

K. Proof of Lemma 7: We have that $\frac{d\tilde{L}(\gamma_0,x,t)}{dx} = -\frac{d\pi_i^S(\gamma_0+x,t)}{dx} = \frac{2\left((\gamma_0+x)^2+(1-x-\gamma_0)\right)\left(2a(a-t)+t^2\right)}{(1+\gamma_0+x)^2(2-\gamma_0-x)^3}$ > 0 for all $t \in (0,\bar{t})$, $\gamma_0 \in (0,1)$ and $x \in (0, 1-\gamma_0)$. *Q.E.D.*

L. Proof of Proposition 6: Recall from (4..6), $\tilde{L}(\gamma_0,x,t) = \pi_i^D(\gamma_0,t) - \pi_i^S(\gamma_0+x,t)$. Define

$$\tilde{h}(\gamma_0,x,t,F) \equiv \frac{F}{2} - \tilde{L}(\gamma_0,x,t).$$

By Assumption 3, $\frac{F}{2} > \tilde{L}(\gamma_0,0,t)$ implies that at $x=0$, we have $\tilde{h}(\gamma_0,0,t,F) > 0$.

Differentiating $\tilde{L}(\gamma_0,x,t)$ with respect to x, we have that

$$\frac{d\tilde{L}(\gamma_0,x,t)}{dx} = \hat{A}t^2 + (a-t)\hat{B},$$

where $\hat{A} = \frac{2\left(x^2+2x\gamma+\gamma^2+(1-\gamma-x)\right)}{(1+x+\gamma)^2(2-x-\gamma)^3} > 0$ and $\tilde{B} = \frac{4a\left(2x\gamma+\gamma^2+x^2+(1-\gamma-x)\right)}{(1+x+\gamma)^2(2-x-\gamma)^3} > 0$ for all $\gamma \in (0,1)$ and $x \in (0, 1-\gamma_0)$. Together with $(a-t) > 0$, we have that $\frac{d\tilde{L}(\gamma_0,x,t)}{dx} > 0$. Now, since $\frac{d\tilde{h}(\gamma_0,x,t,F)}{dx} = -\frac{d\tilde{L}(\gamma_0,x,t)}{dx}$, we have that $\frac{d\tilde{h}(\gamma_0,x,t,F)}{dx} < 0$. Then either
(i) $\tilde{h}(\gamma_0,x,t,F) > 0$ for all $x \in (0,1-\gamma_0)$ or
(ii) there exists $\tilde{x}(t) \in (0,1-\gamma_0)$ such that $\tilde{h}(\gamma_0,x,t,F) \ge 0$ if and only if $x \le \tilde{x}(t)$.

In the case of (i) firms always collaborate for all $x \in (0,1-\gamma_0)$. In the case of (ii), define $x^*(t) = \tilde{x}(t)$. *Q.E.D.*

M. Proof of Lemma 8: We can write the loss from collaboration as follows:

$$\tilde{L}(\gamma_0,x,t) = \grave{A}t^2 + \grave{B}t + \grave{C},$$

where $\grave{A} = \frac{\left(4+\gamma_0^4-3\gamma_0^2\right)}{\left(1-\gamma_0^2\right)\left(4-\gamma_0^2\right)^2} - \frac{(1-x-\gamma_0)}{(1+x+\gamma_0)(2-x-\gamma_0)^2}$, $\grave{B} = \frac{2a(1-x-\gamma_0)}{(1+x+\gamma_0)(2-x-\gamma_0)^2} - \frac{2a(1-\gamma_0)}{(1+\gamma_0)(2-\gamma_0)^2}$ and $\grave{C} = \frac{2\left(2a-a\gamma_0^2-a\gamma_0\right)^2}{\left(1-\gamma_0^2\right)\left(4-\gamma_0^2\right)^2} - \frac{2a^2(1-x-\gamma_0)}{(1+x+\gamma_0)(2-x-\gamma_0)^2}$. Differentiating $\tilde{L}(\gamma_0,x,t)$ we have that

$$\frac{d\tilde{L}(\gamma_0,x,t)}{dt} = 2\grave{A}t + \grave{B}.$$

Substituting $\grave{A}$ and $\grave{B}$, and evaluating at $x=0$, we get $\left.\frac{\partial\tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=0} = \frac{4t\gamma_0(2-\gamma_0^2)}{\left(4-\gamma_0^2\right)^2(1-\gamma_0^2)} > 0$. Together with $\frac{\partial^2\tilde{L}(\gamma_0,x,t)}{\partial t\partial x} = -\frac{4(a-t)\left(x^2+2x\gamma_0+\gamma_0^2+(1-\gamma_0-x)\right)}{(1+x+\gamma_0)^2(2-x-\gamma_0)^3} < 0$ implies the Lemma. *Q.E.D.*

N. Proof of Proposition 7: From (4..11) we have that

$$\frac{dx^*(t)}{dt} = -\left.\frac{\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}}{\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial x}}\right|_{x=x^*(t)}.$$

From Lemma 7, we have $\frac{d\tilde{L}(\gamma_0,x,t)}{dx} > 0$ for all $t \in (0,\bar{t}), \gamma_0 \in (0,1)$ and $x \in (0, 1-\gamma_0)$. So the sign of $\frac{dx^*(t)}{dt}$ depends on the sign of $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}$.

Proof of property (i)

From Lemma 8, we have that

(a) $\left.\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=0} = \frac{4t\gamma_0(2-\gamma_0^2)}{\left(4-\gamma_0^2\right)^2(1-\gamma_0^2)} > 0$, and

(b) $\frac{\partial^2 \tilde{L}(\gamma_0,x,t)}{\partial t \partial x} = -\frac{4(a-t)\left(x^2+2x\gamma_0+\gamma_0^2+(1-\gamma_0-x)\right)}{(1+x+\gamma_0)^2(2-x-\gamma_0)^3} < 0.$

Using mathematical software MAPLE, we have that $\lim_{x\to 1-\gamma_0} \frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t} > 0$ when γ_0 is close to 1 ($\gamma_0 > \hat{\gamma}_0$). This finding together with (a) and (b) implies $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t} > 0$ for all $x \in (0, 1-\gamma_0)$ and in particular $\left.\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=x^*(t)} > 0$. This in turn implies $\frac{dx^*(t)}{dt} < 0$.

Proof of property (ii)

We prove property (ii) using (a) and (b).

(a) From Lemma 8 we have $\left.\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=0} = \frac{4t\gamma_0(2-\gamma_0^2)}{\left(4-\gamma_0^2\right)^2(1-\gamma_0^2)} > 0$. Now consider $\gamma_0 < \hat{\gamma}_0$ and choose F small enough ($F < \hat{F}(\gamma, t)$) such that $x^*(t) < \hat{x}(\gamma_0, t)$. For all such F, applying Lemma 8, we get $\left.\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=x^*(t)} > 0$, since $x^*(t) < \hat{x}(\gamma_0, t)$. Thus $\frac{dx^*(t)}{dt} < 0$.

(b) There exists $\hat{x}(\gamma_0, t)$ such that $\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t} < 0$ for all $x \in (\hat{x}(\gamma_0, t), 1-\gamma_0)$. Choose F large enough ($F > \hat{F}(\gamma, t)$) such that $x^*(t) \in (\hat{x}(\gamma_0, t), 1-\gamma_0)$. For all such F, applying Lemma 8, we get $\left.\frac{\partial \tilde{L}(\gamma_0,x,t)}{\partial t}\right|_{x=x^*(t)} < 0$, since $x^*(t) > \hat{x}(\gamma_0, t)$. Thus $\frac{dx^*(t)}{dt} > 0$. *Q.E.D.*

O. Proof of Lemma 9: Consumer surplus in countries 1 and 2 are given by $CS_1^S(\gamma, t) = \frac{a^2}{(\gamma+1)(\gamma-2)^2}$ and $CS_2^S = \frac{(a-t)^2}{(\gamma+1)(\gamma-2)^2}$ respectively. Summing these two, aggregate consumer surplus can be written as

$$CS(\gamma, t) = \acute{A}t^2 + \acute{B}t + \acute{C},$$

where $\acute{A} = \frac{1}{(1+\gamma)(2-\gamma)^2} > 0$, $\acute{B} = -\frac{2a}{(1+\gamma)(2-\gamma)^2} < 0$, and $\acute{C} = \frac{2a^2}{(1+\gamma)(2-\gamma)^2} > 0$ for all $\gamma \in (0, 1)$. Substituting $\acute{A}$, $\acute{B}$, and $\acute{C}$, and differentiating $CS(\gamma, t)$ we have that

$$\frac{dCS(\gamma, t)}{dt} = -\frac{2\,(a-t)}{(\gamma+1)\,(2-\gamma)^2} < 0$$

for all $\gamma \in (0, 1)$. This implies that consumer surplus in the same country subgame is decreasing in t for all $\gamma \in (0, 1)$ and $t \in (0, \bar{t})$.

Differentiating $CS(\gamma, t)$ with respect to γ, we obtain

$$\frac{dCS^S(\gamma, t)}{d\gamma} = \frac{3\gamma\left(a^2 + (a-t)^2\right)}{(\gamma+1)^2\,(2-\gamma)^3} > 0,$$

for all $\gamma \in (0,1)$. This implies that consumer surplus in the same country subgame is increasing in γ for all $\gamma \in (0,1)$ and $t \in (0,\bar{t})$. *Q.E.D.*

P. Proof of Proposition 8: We have that $CS^S(\gamma,t) - CS^D(\gamma,t) = -t^2 \frac{\gamma^3}{(1-\gamma^2)(4-\gamma^2)^2} < 0$ for all $t \in (0,\bar{t})$ and $\gamma \in (0,1)$. *Q.E.D.*

Q. Proof of Proposition 9: To prove Proposition 9, first we establish the following claim:
Claim: For any $t \in (0,\bar{t})$, there exists $\grave{x}(t) \in (0, 1-\gamma_0)$ such that $CS^D(\gamma_0,t) > CS^S(\gamma_0 + x, t)$ for all $x < \grave{x}(t)$.
Proof: We have that

$$\lim_{x\to 0} CS^S(\gamma_0 + x, t) = CS^S(\gamma_0, t) < CS^D(\gamma_0, t),$$

where the equality follows from continuity of $CS^S(\gamma_0 + x, t)$ in x and the inequality follows from Proposition 8. This implies the claim. *Q.E.D.*

R. Proof of Proposition 10:

Proof of property (i) : First we prove that there exist parameterisations such that an increase in trade cost could lead to higher consumer surplus by encouraging collaboration.

To prove (i) it is sufficient to establish the following claim:
Claim: There exists t_0 and t_1 satisfying $0 < t_0 < t_1 < \bar{t}$ such that $x^*(t_1) > x^*(t_0)$ and $CS^*(t_1) > CS^*(t_0)$.
Proof: Choose $\gamma_0 < \hat{\gamma}_0$ (where $\hat{\gamma}_0$ is defined in Proposition 7) and $F > \hat{F}(\gamma, t)$. Then, by Proposition 7, $x^*(t_1) > x^*(t_0)$ where $t_1 > t_0$. Now, choose $t_0 = 0$, $t_1 = \delta$ and $x = x^*(\delta)$. Since $x^*(\delta) > x^*(0)$, then

$$\begin{aligned} CS^*(t_0) &= CS^*(0) = CS^D(\gamma_0, 0) \\ CS^*(t_1) &= CS^*(\delta) = CS^S(\gamma_0 + x^*(\delta), \delta). \end{aligned}$$

Applying limits, we have $\lim_{\delta\to 0} CS^*(\delta) = \lim_{\delta\to 0} CS^S(\gamma_0 + x^*(\delta), \delta) = CS^S(\gamma_0 + x^*(0), 0) = CS^D(\gamma_0 + x^*(0), 0) > CS^D(\gamma_0, 0)$. Then applying continuity arguments, it is easy to show that for appropriate values of t_0 and t_1, an increase in trade costs from t_0 to t_1 can increase consumer surplus. This implies the claim.

Proof of property (ii)

To prove (ii) it is sufficient to establish the following claim:
Claim: There exists t_0 and t_1 satisfying $0 < t_0 < t_1 < \bar{t}$ such that $x^*(t_1) < x^*(t_0)$ and $CS^*(t_1) > CS^*(t_0)$.
Proof: Choose $\gamma_0 > \hat{\gamma}_0$ or $\gamma_0 < \hat{\gamma}_0$ (where $\hat{\gamma}_0$ is defined in Proposition 7) and $F < \hat{F}(\gamma, t)$. Then, $x^*(t_1) < x^*(t_0)$ for all t_0 and t_1 satisfying $t_1 > t_0$. Let $t_1 = t_0 + \delta$, where $\delta > 0$. Pick $x = x^*(t_0)$. Since $x = x^*(t_0) > x = x^*(t_0 + \delta)$, firms do not collaborate if $t = t_0 + \delta$ and hence

$$CS^*(t_0 + \delta) = CS^D(\gamma_0, t_0 + \delta).$$

On the other hand, at $x = x^*(t_0)$, firms collaborate if $t = t_0$. Hence

$$CS^*(t_0) = CS^S(\gamma_0 + x^*(t_0), t_0).$$

Applying limits, we have $\lim_{\delta \to 0} CS^*(t_0 + \delta) = CS^D(\gamma_0, t_0)$. Now, as $F \to 0$, we have that $x^*(t_0) \to 0$. This implies that $CS^S(\gamma_0 + x^*(t_0), t_0) \simeq CS^S(\gamma_0, t_0)$. Proposition 8 tells us that $CS^D(\gamma, t_0) - CS^S(\gamma, t_0) > 0$. Then applying continuity arguments, it is easy to show that an increase in trade costs from an appropriate value of t_0 to an appropriate value of t_1 can increase consumer surplus. This implies the claim. *Q.E.D.*

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