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

In recent years the incidence and importance of collaborations and strategic alliances (SAs) has increased tremendously across the globe (Oster 1994). The existence of competitor collaborations is prominent in the Automobile, Pharmaceutical, Semiconductor and Liquid Crystal Display (LCD) industries. In automobile industry, Renault and Nissan, for example, share key components such as engines, axles and transmission, and save their 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 as well. In the pharmaceutical industry, it is common for a company to distribute its foreign competitors' products through its own domestic distribution channel, with reciprocal arrangements at the other end (Ohmae 1993). By not building their own distribution networks from scratch, they can save large amounts in fixed costs. A similar example in the microprocessor industry is how IBM, Sony Group and Toshiba have collaborated in developing a high-performance microprocessor (named Cell) for four years since 2001.[1] Likewise, in the LCD industry, Samsung and Sony jointly established a company to manufacture LCD panels for flat-panel TVs. The jointly established manufacturer provide the two companies with LCD panels for each company's LCD TVs.[2]

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[1] See http://www.toshiba.co.jp/about/press/2005_02/pr3101.htm

[2] See http://news.com.com/Japanese+makers+forge+1+billion+LCD+alliance/2100-1041_3-5331665.html

We are interested in the class of collaborations where firms remain competitors in the product market while they collaborate in a variety of different stages on their value-creating activities such as technology development, product design, and distribution. Ohmae (2002) pointed out that a number of competing US and Japanese firms had established collaborations in the semiconductor industry to save on fixed R&D costs. As the above examples illustrate, one of the main purpose of collaborations is to obtain a cost advantage by jointly exploiting economics of scale (Barney, 2002). Sharing a part of their value-creating activities, which consists of technology development, product design, manufacturing, marketing, distribution, and services firms save costs. Ohmae (1993) pointed out that companies in the pharmaceutical industry can save large amounts in fixed cost by not building their own distribution networks from scratch. In the areas of research and development (R&D), Ohmae pointed out that a number of competing US and Japanese firms had established collaborations in the semiconductor industry to save on fixed R&D costs.

The crucial disadvantage of collaboration is manifested by the reduction in the firms' product distinctiveness. As illustrated by examples mentioned above, competitors often collaborate by sharing a part of their value-creating activities, which consist of technology development, product design, manufacturing, marketing, distribution, and services.[3] These activities are important elements for creating product distinctiveness across firms. Caves and Williamson (1985) empirically derived five important bases of product differentiation: products customized for specific customers, product complexity, emphasis on consumer marketing, different distribution channels, and service and support. By sharing key components such as high-performance microprocessors, LCD panels, and engines, competitors can save on costs for technology development, product design, and manufacturing at the expense of reducing their product distinctiveness. We consider international collaborations (among competing firms), which exhibit this trade-off (as discussed in Ghosh and Morita).

A significant number of the recent competitor collaborations agreements have been between international firms. Between 1980 and 1990, Japanese firms and American firms agreed on over five hundred collaboration arrangements (Oster, 1994). Kang and Sakai (2000) have found that the number of international collaborations grew more than five-time between 1989 and 1999. Narura and Hagedoorn (1997) suggest that about 65% of collaboration 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. These examples of the worldwide trend in International collaboration is exemplified by Nissan and Renault. They plan to reduce the number of platforms they use to 10 in 2010 from the 34 they had in 2000 (see Tierney et al. (2000)).

Our paper analyzes the incentives and welfare implications of such international collaborations. We explore the relationship between trade cost and incentives to collaborate in a two-stage model with collaboration decisions followed by price competition. The extended model endogenizes firms' location decisions by incorporating a non-cooperative location choices before collaboration decisions then characterizes the equilibria of the game.

An outline of the model is as follows: Suppose there are two countries 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 locates in country 1 and firm 2 locates in country 2. Firms decide cooperatively whether to collaborate

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

or not. Collaboration ((i) reduces fixed product development costs of 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 in prices. 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 determines whether to locate in country 1 or 2. We introduce a fixed coordination cost k. Under collaboration, let us assume that $k = 0$ if they are located in the same country, and $k = k\prime (\geq 0)$ otherwise. If firms do not collaborate they do not need to coordinate. After location choices and collaboration decisions, firms compete in prices.

Given that collaboration reduces product distinctiveness, naturally firms collaborate when reduction in product distinctiveness is less than a certain threshold. We find that when coordination cost of collaboration (which is strictly positive only when firms are in different countries) is low the threshold increases as tariff/trade-cost increases. That is, a reduction in tariffs/trade costs increases the incentives to collaborate. Though collaboration reduces 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. We find that when coordination cost of collaboration is high, so that firms have to locate in the same country for collaboration, an increase in trade cost might lower the incentives for collaboration.

Although competitors collaborate in a variety of ways in reality, most previous papers on economic theoretical analyses of competitor collaborations have primarily focused in the context of research joint ventures in oligopolies with R&D spillovers (see, e.g., Chen and Ross, 2003; Motta, 1996; Steurs, 1995). Katz (1986) explored a four-stage model in which firms in an industry form a cooperative (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 Jacqumin (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, where the cooperative R&D is modelled as the joint determination of the levels of their R&D investments. In the context of stochastic R&D, Choi (1993) captured the idea that a cooperative R&D agreement may intensify product-market competition among participants in his two-firm model. While research joint ventures constitute an important example of collaboration, the existing models do not capture the trade-off between fixed-cost savings and reduced product distinctiveness, which underpin a large class of real world collaborations. Chen (2003) studies international alliances in context of homogenous product Cournot duopoly in an international setting (as in Brander and Krugman, 1983). Morasch (2000) examines whether strategic alliance (in the form of an input joint venture) can act as a substitute for strategic trade policy. As in our model, these collaborations generate cost savings however there is no reduction in product distinctiveness. Ghosh and Morita (2006) however, explores the economic consequences of the trade-off between product distinctiveness and fixd-cost savings by analyzing models that incorporate competitor collaboration into the location framework. We contribute to this line of investigations by exploring economic consequences of competitor collaborations that reduce the degree of product distinctiveness of a Bertrand duopoly. The extent to which collaboration costs effect firms' location choice is also investigated in the extension part of our model.

The rest of the paper is organized as follows. Section2 develops the model where firms make location and collaboration decisions. Section 3 explores the relationship between trade cost and competitor collaboration in addition to welfare implication under low communication cost environment, and Section 4 explores the relationship between trade cost and competitor collaboration in addition to welfare implication under high communication cost environment. Section 5 concludes.

2. The Model

Consider an industry consisting of two firms, firm 1 and firm 2, each producing a differentiated good. Firms compete in Bertrand fashion. There are two countries denoted 1 and 2. Firm 1 is located in country 1 and serves country 2 via export whilst firm 2 is located in country 2 and export to country 1. We consider an extension of Ghosh and Morita (2006) in an international context.

Each firm i produces product $i = \{1, 2\}$, where p_{ij} and q_{ij} denote firm i's price and quantity in country $j = \{1, 2\}$ respectively. Assume that there are linear demand for the products in each market. In each country, there is a continuum of consumers of the same type, and the representative consumer's preferences are described by the utility function, $U(q_1, q_2) + q_0$, where $U(q_1, q_2) = a(q_1 + q_2) - (q_1^2 + 2\gamma q_1 q_2 + q_2^2)/2$, $a > 0$, (as discussed in Dixit 1979; and Singh and Vive 1984). The parameter γ represents the degree of product differentiation where goods are substitutes, independent, or complements according to whether $\gamma > 0$, $\gamma = 0$, or $\gamma < 0$ respectively. Corresponding to this utility specification, the inverse demand function for product 1 and 2 in country j are

$$p_{1j} = a - q_{1j} - \gamma q_{2j}, \; j = 1, 2, \quad (2..1)$$
$$p_{2j} = a - q_{2j} - \gamma q_{1j}, \; j = 1, 2. \quad (2..2)$$

Inverting the inverse demand yields the direct demands,

$$q_{1j} = \frac{(a - \gamma a + \gamma p_{2j} - p_{1j})}{(1 - \gamma^2)} \equiv q_{1j}(p_{1j}, p_{2j}), \quad (2..3)$$
$$q_{2j} = \frac{(a - \gamma a + \gamma p_{1j} - p_{2j})}{(1 - \gamma^2)} \equiv q_{2j}(p_{1j}, p_{2j}). \quad (2..4)$$

where $a > 0$. The direct demand function for firm i is downward-sloping in her own price and is an increasing (decreasing) function of her rival's price if the goods are substitutes (complements). In the following analysis, we restrict our attention to the case where goods are product substitutes, $\gamma \in (0, 1)$. The degree of product differentiation decreases as γ increase. Because the direct demand functions are not defined for the case of $\gamma = 1$, we will not be analysing the case of perfect substitutes. By symmetry, firm i's demand when selling in the home and foreign country is the same.

There are three types of costs. The first is the per unit marginal cost. For simplicity, we assume both firms have the same production technology and marginal cost of production is 0. The second is the fixed investment cost. Firm i must incur a fixed product design cost denoted by $F_i > 0$ before they can produce. The third type of cost is the trade cost or transportation cost denoted by t. This includes all costs of shipping each unit of the production trans-border and can include product shipment cost, tariffs or any other import taxes. In what follows, we use 'trade cost' and 'transportation cost' interchangeably. We assume that transportation cost is bilateral. The cost of transporting goods between country 1 and 2 must be the same both ways.[4]

Firms engage in a two-stage game.

Stage 1 [Collaboration decision]: Firms 1 and 2 decide jointly whether or not to collaborate. If firms do not collaborate then $\gamma = \gamma_0$ and $F_i = F$ where $i = 1, 2$. Conversely, if firms collaborate then $\gamma = \gamma_0 + x$ and $F_i = \frac{F}{2}$ where $i = 1, 2$. That is, each firm $i = 1, 2$ shares the cost savings $\frac{F}{2}$ equally if they collaborate. Competitor collaboration takes place if and only if two firms mutually agree to collaborate.

Stage 2 [Product market competition]: Given the collaboration decision in stage 2, each firm i chooses price p_{ij} to maximise its own profit in country j $(i = 1, 2)$, taking its rival's price as given. We assume that competitor collaboration (if it occurs) does not lead to any collusion in the product market competition stage.

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). To solve for equilbria of the game, we determine the equilibrium of the subgames in stage 2. Analysis of this subgame provides the equilibrium profits and quantities, which impact the collaboration decision in stage 1. Then, we derive an equilibrium of the entrie 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 SPNE outcome is maximised. For simplicity, we assume that if firms are indifferent between collaborating and not collaborating, they choose to collaborate.

The summary of the games is described in figures 1.

[4] This is implicily assuming that both countries have a bilateral trade agreement. Both countries must set the same tariffs if they decide to impose trade protection.

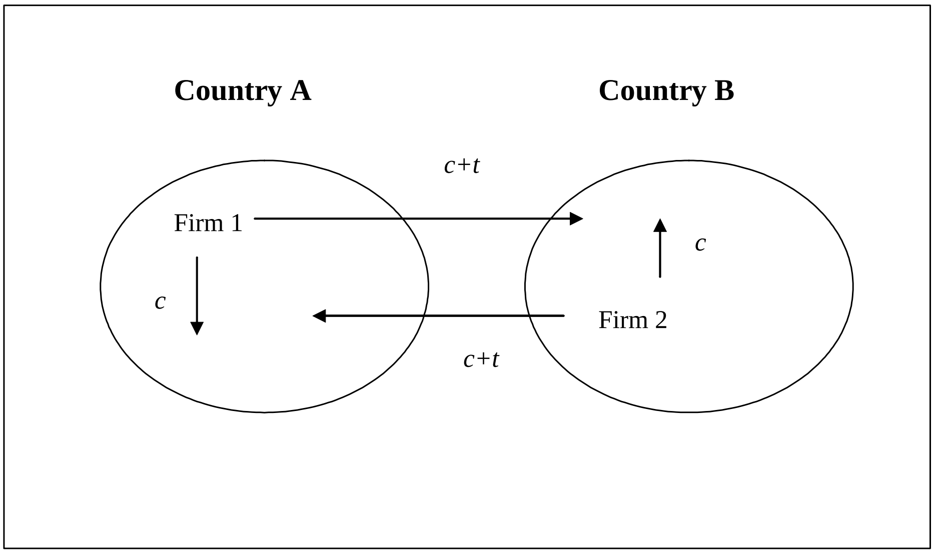

Figure 1: Summary of the game

In stage 2, firm 1 chooses p_{1j} to maximise the variable profit functions from selling in countries 1 and 2. The maximisation problem is given by

$$\max_{\{p_{1j}\in R^{+}\}} \sum_{j=1}^{2} \pi_{1j} = \sum_{j=1}^{2} [p_{1j} - c_{1j}] q_{1j}(p_{1j}, p_{2j}) \text{ where } j = 1, 2 \text{ and,} \tag{3..1}$$

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

This maximisation problem leads to the equilibrium price function

$$p^{*}_{1j}(\gamma, t) = \begin{cases} \frac{\left(2a+t\gamma-a\gamma^{2}-a\gamma\right)}{(4-\gamma^{2})} & \text{if } i = j \\ \frac{\left(2a+2t-a\gamma^{2}-a\gamma\right)}{(4-\gamma^{2})} & \text{if } i \neq j, \end{cases} \tag{3..2}$$

and equilibrium profit function

$$\pi^{*}_{1j}(\gamma, t) = \begin{cases} \frac{\left(2a+t\gamma-a\gamma^{2}-a\gamma\right)^{2}}{(1-\gamma^{2})(4-\gamma^{2})^{2}} & \text{if } i = j \\ \frac{\left(2a+t\gamma^{2}-a\gamma^{2}-a\gamma-2t\right)^{2}}{(1-\gamma^{2})(4-\gamma^{2})^{2}} & \text{if } i \neq j, \end{cases} \tag{3..3}$$

respectively. By symmetry, firm 2's maximization problem leads to the same equilibrium prices and profits as firm 1.

We impose two assumptions on the limitation of fixed cost throughout the paper. The model requires the net profits in the collaboration and no collaboration subgames must be positive. This implies

Assumption 1: $F < \min\{\pi_i(\gamma_0, t), 2\pi_i(\gamma_0 + x, t)\} = F'$[5].

[5] This implies $\Pi_i = \pi_i(\gamma_0, t) - F > 0$ and $\Pi_i = \pi_i(\gamma_0 + x, t) - F/2 \geq 0$.

The value of fixed cost associated with product design or platform innovation incurred by firm i must be lower than the minimum of its profits with collaboration and twice the profit without collaboration. Clearly, without the restriction on fixed cost, competitor collaboration may not be possible as firms find it unprofitable to produce. This assmption ensures that both firms produce in both collaboration subgames in SPNE.

We impose another assumption on our analysis of trade cost.

Assumption 2: Define $\bar{t}(\gamma) = \frac{1}{2-\gamma^2}\left(2a - a\gamma - a\gamma^2\right)$, we limit trade cost to $t < \min(\bar{t}(\gamma_0), \bar{t}(\gamma_0 + x))$.

The function $\bar{t}(\gamma)$ represents the the maximum value of t where firm i finds it unprofitable to export to country j. To ensure that firm i produces in both countries, trade cost must be sufficiently low. If trade cost is higher than $\bar{t}(\gamma)$, firm i will find it unprofitble to export and become a domestic monopoly. We impose a condition that trade cost in our analysis is lower than the threshold in both the collaboration and no collaboration subgames, and both firms produce in both countries in equilibrium.

Because both firms supply in both countries, firm i's total profit in each stage 2 payoffs are given by it's sum of profits by selling in country 1 and country 2 denoted by

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

Thus, firm i's equilibrium profits under each stage 2 subgames are

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

respectively.

3.1. Characterization of equilibrium

In this subsection, we characterize the equilibrium of the game and identify the conditions under which firms 1 and 2 collaborate at stage 2 in equilibrium.

Stage 1: In the collaboration subgame, each firm gains a reduction in fixed product innovation cost $\frac{F}{2}$. Competitor collaboration can occur if and only if the total profits denoted by Π where $\Pi_i \equiv \pi_i(\gamma, t) - F_i$ from collaboration is greater than total profits from no collaboration.[6] This condition is captured by

$$L(\gamma_0, x, t) \leq \frac{F}{2}, \tag{3..6}$$

where the loss from competitor collaboration is defined as

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

where $\pi_i(\gamma_0, t) = \pi_{i1}(\gamma_0, t) + \pi_{i2}(\gamma_0, t)$ and $\pi_i(\gamma_0 + x, t) = \pi_{i1}(\gamma_0 + x, t) + \pi_{i2}(\gamma_0 + x, t)$. Clearly, firm i chooses to collaborate if $L(\gamma_0, x, t)$, the loss from collaboration is lower than or equal to the gain from collaboration $\frac{F}{2}$. Conversely, suppose their loss from competitor collaboration is greater than $\frac{F}{2}$, firm i should not collaborate since the cost is higher.

[6] Here, I must mention that the term "joint profits" means the sum of an individual firm's profit in the home country and foreign country. Furthermore, an individual firm's profit in a market is obtained from maximizing his profit subject to the environment – demand, cost, competition and transportation cost – of that market.

3.2. When does firm i collaborate?

The effect of x on firm i's profit in the collaboration subgame is captured in Lemma 1 and 2.

Lemma 1 *For $t \in (\tilde{t}, \bar{t})$, $L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t) = 0$ at $x = 0$. Because $L(\gamma_0, x, t)$ is decreasing in x for all $x \in (0, 1 - \gamma_0)$, $L(\gamma_0, x, t) < 0$. i.e. $\frac{dL(\gamma_0,x,t)}{dx} < 0$.*[7]

For high trade cost, there exist an additional gain from collaboration on top of the fixed cost saving $\frac{F}{2}$. Consider the status quo where firms are not collaborating. For arbitrary small values of x (low loss from product distinctiveness), the loss from collaboration is significantly small and $\pi_i(\gamma_0, t) \equiv \pi_i(\gamma_0 + x, t)$ implying firms are indifferent between collaboration and no collaboration. For $x \in (0, 1 - \gamma_0)$, both firms charge lower prices in both countries if they collaborate. This is because competition is more intensified due to products are becoming more homogenous. This affect firm i's profitability in its domestic and foreign countries differently. On the one hand, firm i's profit in the foreign country decreases due to product homogeneity and its large cost disadvantage. On the other hand, because products are more homogenous, firm i's cost advantage allows it to capture a larger market share relative to its foreign competitor. Although both firms' prices are lower in both countries, firm i's profit in its domestic market increase due to it's larger market share. The increase in domestic profits outweights the loss in profits in the foreign country when cost asymmetry between firms are high. For high trade cost, the loss from collaboration is decreasing for the parameter $x \in (0, 1 - \gamma_0)$.

Proposition 1 *Firms always collaborate for all $x \in (0, 1 - \gamma_0)$ when $t \in (\tilde{t}, \bar{t})$.*

By Lemma 1, firms gain by collaborating when the cost asymmetry from trade cost is high. Firm i's total gain from collaboration is the sum of cost savings $\frac{F}{2}$, and higher profits as it captures a larger share in the domestic market when products are more homogenous. Thus, there is no trade off from collaboration and firms always collaborate for the parameter $t \in (\tilde{t}, \bar{t})$.

Lemma 2 *For $t \in [0, \tilde{t})$, $L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t) = 0$ at $x = 0$. Because $L(\gamma_0, x, t)$ is increasing in x for all $x \in (0, 1 - \gamma_0)$, $L(\gamma_0, x, t) > 0$. i.e. $\frac{dL(\gamma_0,x,t)}{dx} > 0$.*

Contrary to the previous Lemma, when cost asymmetry is low, firms loose by switching to collaboration. For arbitrary small values of x (low loss from product distinctiveness), the loss from collaboration is significantly small and $\pi_i(\gamma_0, t) \equiv \pi_i(\gamma_0 + x, t)$ and $L(\gamma_0, x, t) = 0$. In contrast, when the loss in product distinctiveness is high, products become almost homogeneous and firms compete more fiercely in price. Subsequently, profits in the collaboration subgame approaches the Homogenous Bertrand profit of 0 ($\lim_{x \to 1-\gamma_0} \pi_i(\gamma_0 + x, t) = 0$). Here, the cost asymmetry is not large enough for firms to capture larger market share domestically and thus, domestic profit does not increase. Firm i's profit in the no collaboration subgame is not affected by x, hence $\frac{dL(\gamma_0,x,t)}{dx} > 0$.

Given Lemma 2, Proposition 2 below identifies the condition in which firms 1 and 2 choose to collaborate.

[7] Here, we find $0 < \tilde{t}(\gamma) < \bar{t}(\gamma)$ for all $\gamma \in (0, 1)$. Refer to Appendix for the function $\tilde{t}(\gamma)$.

Proposition 2 *There exist a function $x^*(t)$ such that firms 1 and 2 collaborate at Stage 1 in the unique equilibrium outcome if and only if $x \leq x^*(t)$, where $x^* \in (0, 1-\gamma_0)$ and $t \in [0, \tilde{t})$.*

Lemma 1 tells us that the loss from collaboration function is increasing in x. For smaller values of x, the loss in product distinctiveness is small and thus, the differences between profits without and with collaboration is small. For larger values of x, products become almost homogenous if firms collaborate. Therefore, profits in the collaboration subgame approaches 0 and loss in profits is high. Since the advantage of the collaboration (reduction in fixed-cost saving) $\frac{F}{2}$ is not affected by x, firms 1 and 2 choose to collaborate when x is relatively small. The function $x^*(t)$ depicts the value of the loss in product distinctiveness where firms are indifferent between collaboration and no collaboration.

In the figure below, for $x > x^*(t)$, the degree of loss in product distinctiveness from collaboration leads to a loss in profit that outweighs cost saving from collaboration. On the other hand, when $x < x^*(t)$, loss in profit from collaboration is relatively small and firms should collaborate.

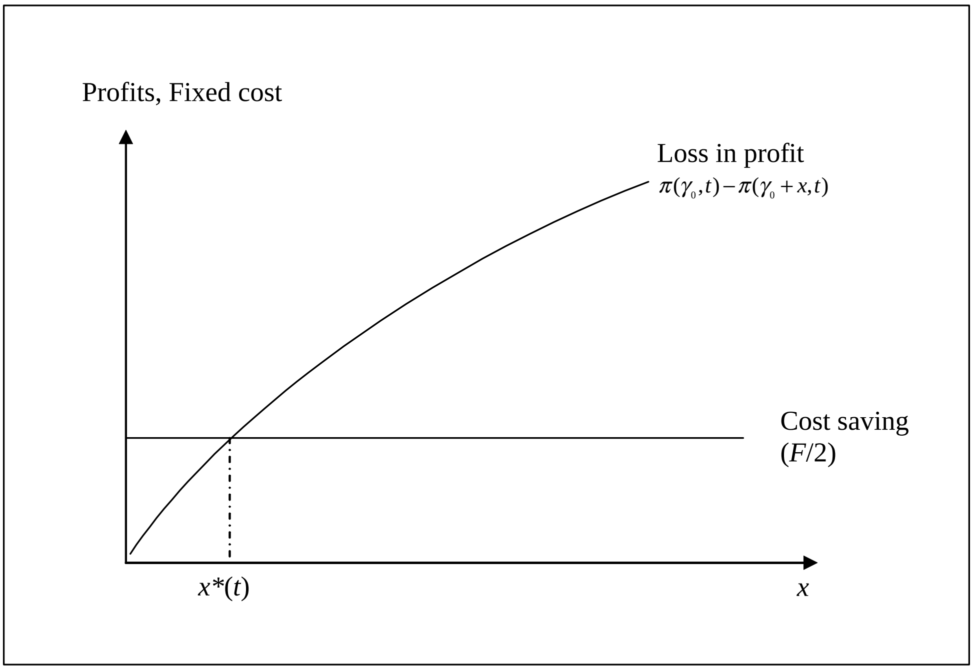

Figure 2: Proposition1

3.3. How does trade cost affect collaboration?

Next we analyse how the trade cost affect the strategic interaction between collaborators. In a standard two-firm two-country model, higher transporation cost means it is more difficult for firm i to sell its product trans-border. Firm i's product in its export market is less attractive to foreign consumer due its price being higher as a result of higher per unit trade cost. When trade cost increases, firm i can charge a higher price in its domestic market and still increase its quantity sold.[8] Nevertheless, due to the symmetry of the model, firm i's profit from exporting declines. Higher trade cost mitigates competition among firms by segmenting the market for product i.

The effect of higher transportation cost on firm i's overall profitability is not obvious (Brander and Krugman, 1983). Higher transportation cost effects firm i's total profitability in two ways. On the one hand, firm i's profitability in its domestic market increase due to lesser foreign competition. On the other hand, firm i's profitability in its foreign market declines. Now, we investigate how transportation cost affect firm i's collaboration decision. The effect of t on the loss from collaboration function is captured in lemma 2.

Lemma 3 *For all $x \in (0, 1-\gamma_0)$, we have $\frac{dL(\gamma_0,x,t)}{dt} < 0 \forall t \in [0, \bar{t})$.*

This Lemma implies that firm i's total loss from collaboration is always decreasing in t ceteris paribus. The effect of higher trade cost on firm i's profit in each collaboration subgames are ambiguous. However, for any given $x \in (0, 1-\gamma_0)$, the loss from collaboration declines as trade cost increases.

The intuition is as follows: Lemma 1 suggests that for any given $x \in (0, 1-\gamma_0)$, both firms' prices and profits in both countries are lower in the collaboration subgames. This is because competition is more intensified when products are more homogenous. However, as trade cost increase, there will be higher cost asymmetry between firms under both no collaboration and collaboration subgames. Therefore, as trade cost increases, firm i can capture a larger share in its domestic market and receives higher total profits (or lower loss) when products are more homogenous. This means that the postive (negative) effect of trade cost on total profits when firms collaborate is relatively higher (lower) in the collaboration subgame than no collaboration subgame. For a given $x \in (0, 1-\gamma_0)$, the loss from collaboration is decreasing in trade cost for the parameter $t \in [0, \bar{t})$.

Proposition 3 *Higher transportation cost encourages competitor collaborations, $x^{*\prime}(t) > 0$ for all $t \geq 0$.*

Proposition 2 tells us that there exist a function $x^*(t)$ where firm i is indifferent between collaboration and no collaboration. Moreover, firm i should collaborate if x is lower than $x^*(t)$. By Lemma 3, the loss from collaboration for any $x \in (0, 1-\gamma_0)$ declines with t. Since the advantage of collaboration (fixed-cost savings) is unaffected by x, an increase in transportation cost indicates a new threshold point where firms are indifferent between collaboration and no collaboration. The intuition is as follow: An increase in t reduces competition between firms in both countries, thus firms can afford to withstand greater reduction in distinctiveness from collaboration.[9]

3.4. Effects of competitor collaboration on Welfare

Now we investigate the effects of trade cost on consumers with the possbility of competitor collaborations. In the literature, most trade practitioners have always believed that trade cost

[8] Here, higher trade cost forces the foreign firm to increase its export price. Firm i's strategic choice is to increase its domestic price by less than its foreign counterpart and increase its quantity sold.

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

has an adverse effect on welfare. Trade cost serves as a protection to the domestic firm as it allows the local firm to behave like a monopoly even when products are homogenous. As trade cost increases, firm i charges higher prices in both its domestic and foreign countries and subsequently, markets become more segmented and there is an increased waste due to transport costs (Brander and Krugman, 1983).

With the possibility of collaboration, Proposition 2 suggests that an increase in trade cost can alter collaboration decision in SPNE. The change in collaboration decision has two effects on welfare. First, a collaboration between firms 1 and 2 reduces the distinctiveness between their products, which *directly* affects consumers' utility by changing product characteristics. Collaboration reduces the degree of product differentiation and the utility of the representative consumer who prefers product variety. Second, collaboration also affects the intensity of competition among both firms, which *indirectly* affects consumers through equilibrium prices. Firms charge lower prices and output is greater in the collaboration subgame than in the non collaboration subgame. This increases the utility of the representative consumer who pays lower price and enjoy higher quantity. The impact of trade cost on collaboration decision yields rich implications on how the interaction of the product-characteristics effect and the price effect affects consumers.

We categorize consumers into two groups. The first group is consumers in country 1 and the second is consumers in country 2. Each country has its own representative consumer's utility function. Consumers in country 1 and 2 may purchase from firm 1 or firm 2. Due to the symmetry of the model, welfare in both countries are the same. For the purpose of welfare analysis, let $CS_j(\gamma, t)$ denote the consumer surplus of the representative consumer in country j $(j = 1, 2)$ for a given differentiation parameter γ and trade cost t,.

Lemma 4 investigates the relationship of trade cost t and degree of product distinctiveness γ on welfare. Moreover, Lemma 4 indentifies how a change in transportation cost effect welfare and Lemma 5 investigates how a change in collaboration decision effect welfare ceteris paribus.

Lemma 4 *Consumer surplus in country j is decreasing in t for all $t \in [0, \bar{t})$ and increasing in γ for all $\gamma \in (0, 1)$. More formally:*

((i)$\frac{dCS_j(\gamma,t)}{dt} < 0$ *for all* $t \in [0, \bar{t})$.

(ii) $\frac{dCS_j(\gamma,t)}{d\gamma} > 0$ *for all* $\gamma \in (0, 1)$.

The first property confirms the conventional effect of trade cost on welfare. An increase in trade cost reduces welfare ceteris paribus. For the second property, the degree of product distinctiveness increases from $\gamma = \gamma_0$ to $\gamma = \gamma_0 + x$ as firms switch from no collaboration to collaboration. Because consumer surplus is increasing in γ, welfare is always higher when firms collaborate ceteris paribus. From the consumers' point of view, the positive effect on consumer surplus resulted from a decrease in prices (Price effect) dominates the negative effect on consumer surplus resulted from lower degree of product distinctiveness (Product-characteristics effect) and welfare is always higher when firms collaborate. This implies that $CS_j(\gamma_0, t) < CS_j(\gamma_0 + x, t)$ must hold for $x \in (0, 1 - \gamma_0)$.

Define the equilibrium consumer surplus in SPNE for any given t as

$$CS_j^*(t) = \begin{cases} CS_j(\gamma_0 + x, t) \text{ if } x \leq x^*(t) \\ CS_j(\gamma_0, t) \text{ if } x > x^*(t). \end{cases} \tag{3..8}$$

The inverse effect of t and γ on welfare yields rich welfare implication with the possibility of collaboration. Surprisingly, we find that contrary to the conventional belief that trade cost has adverse effect on welfare, higher trade cost can be welfare improving with the possibility of collaboration. First, we present the parameterizations of x where an increase in trade cost does not change collaboration decision in SPNE. Then, we present the parameterization of x where an increase in trade cost does change collaboration decision in SPNE.

Proposition 4 *Consider an increase in t from $t = t_0$ to $t = t_1$ where $0 \leq t_0 < t_1 < \tilde{t}$. Then, consumer surplus in country j is decreasing in t for all $x \notin (x^*(t_0), x^*(t_1)]$.*[10]

From proposition 2, when the degree of loss in product distinctiveness from collaboration is small, $x \in (0, x^*(t_0)]$, an increase in trade cost reduces the relatively insignificant loss from collaboration and firms continue to collaborate. Here, trade cost segments the market further even when product distinctiveness is low. Hence, consumer surplus declines as higher cost asymmetry allows firms to increase their prices.

For high loss in product distinctiveness from collaboration, $x \in (x^*(t_1), 1 - \gamma_0)$, the loss from collaboration is high as products are almost homogenous when firms collaborate. Although higher trade cost reduces the loss from collaboration, it is not suffice to induce firms to collaborate. Consumer surplus declines for the same reason as when $x \in (0, x^*(t_0)]$.

Proposition 5 *For any $t_0 \in [0, \bar{t})$, there exist $t_1 \in (t_0, \bar{t})$ and $x \in (x^*(t_0), x^*(t_1)]$ such that $CS^*(t_0) < CS^*(t_1)$. In other words, consumer surplus can be higher with an increase in trade cost.*

For intermediate value of the loss from collaboration, $x \in (x^*(t_0), x^*(t_1)]$, an increase in trade cost from t_0 to t_1 reduces the loss from collaboration to a value lower than fixed cost savings $\frac{F}{2}$. This induces firms to switch from no collaboration to collaboration in stage 1 SPNE. This change in equilibrium outcome affects welfare in two ways. First, increasing trade cost mitigates competition and reduces welfare. Higher trade cost protects the domestic producer against foreign competition. Firms charge higher prices and sell more in their domestic markets while exporting less. Higher prices results in lower quantities sold and subsequently reduces welfare.

Second, higher trade cost reduces the loss from collaboration and induces firms to collaborate in SPNE. As a result, products become more homogenous and firms compete more fiercely. Because price effect dominates product-characteristics effect, the decline in prices as a result of collaboration increases consumers' welfare.

This proposition suggests that there exist a value $x \in (x^*(t_0), x^*(t_1))$ such that consumer surplus is higher as a result of higher trade cost. In the context of competitor collaboration, the establishment of trade cost could be viewed as an anticompetitive activity that results in higher consumer surplus when accompanied by collaboration because it induces firms to collaborate at the expense of reduced product variety but lower price.

Figure 3 summarizes the relationship between t and $x^*(t)$ as described in Propositions 4 and 5. For any increase in trade cost 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 $x \in (0, x^*(t_1)]$. There are three important parameterizations of x that describes the SPNE.

[10] Additionally, for any $t \in (\tilde{t}, \bar{t})$ and increase in t from t_0 to t_1 where $\tilde{t} < t_0 < t_1 < \bar{t}$ results in lower welfare in both countries. From Proposition 1, for the parameterization $t \in (\tilde{t}, \bar{t})$, firms always collaborate since they gain additional gain from collaobration to the fixed cost savings $F/2$. An increase in trade cost doesn't switch collaboration decision and hence, welfare in both countries decline.

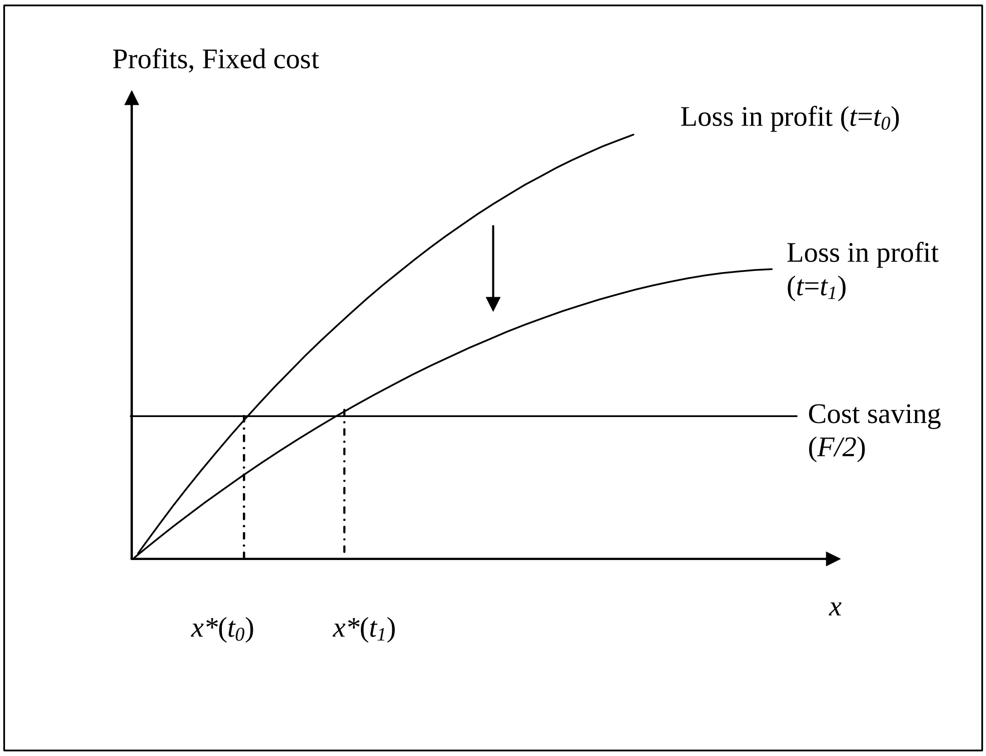

Figure 3:

4. The Game incorporating a Location choice

Hitherto, we have analysed competitor collaboration in a standard international trade settings where firms locate in different countries (as discussed in Brander and Krugman, 1983). In the real world however, firms put as much emphasis on choosing their optimum location choice as collaboration decision. In practice, firms often choose to co-locate when they collaborate for two main reasons.

First, collaborators have no other choice but to locate in the same countries when they jointly invest in infrastructures or key assets. In a production collaborations, participants are required to jointly build factories and/or invest in machineries 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.[11] The jointly established manufacturing facility in Mobara, Japan, provide the three companies with LCD panels for each company's LCD TVs (Kang and Sakai, 2000).[12]

[11] http://news.com.com/Japanese+makers+forge+1+billion+LCD+alliance/2100-1041_3-5331665.html

[12] On the other hand, S-LCD – a collaboration company formed by Samsung and Sony – has a LCD manufacturing facility in South Korea that produces LCD screens for both Samsung and Sony. (http://news.com.com/Japanese+makers+forge+1+billion+LCD+alliance/2100-1041_3-5331665.html)Also, Toyota and GM established New United Motor Manufacturing Inc. (NUMMI) in 1984 in a shuttered GM plant to build both Toyotas and GM cars using the same unionized work force, production

Second, collaborators choose to locate in the same countries to benefit from knowledge spillovers while saving communication cost. Knowledge spillover is natural under both R&D and production collaborations. In a R&D collaboration, firms benefit from spillovers as their engineers share their know-how, resources and experience to develop a new or improved goods or production processes more efficiently and move into technological areas beyond their national reach (Draper, 1990). Likewise, in a production collaboration, firms share their learning and know-how of their production processes and benefit from each other's proprietary knowledge and economies of scale and scope (Draper, 1990).[13]

With collaboration, firms could be in the lower part of the learning curve when spillovers and information flows from collaboration are local. Nevertheless, collaborators incur another type of cost to achieve these spillovers known as 'Communication cost'. This cost involves the cost of voice and/or data communications between firms during the R&D or production stage. By locating in different countries, the cost to convey key findings or knowledge might be too costly for firms to collaborate since engineers from the collaborating firms are required to work closely together while developing the product. If communication is extremely costly, the only way firms can collaborate is to locate in the same country even if they do not engage in joint investment in infrastructures. For example, in 2001, Toshiba and Sony saved communication cost by transferring their engineers to work at Toshiba's research centre in Shinsugita, Yokohama, near Tokyo while developing the 90-nanometer and 65-nm process nodes DRAM structure.[14]

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.

4.1. The Model

In this extension, everything is the same as in the original model analyzed in the previous section, except that we incorporate a location decision node before Stage 1 call Stage 0. We consider the three-stage game described below, in which the two competitors can collaborate in order to save their fixed cost.

Stage 0 [Location decision]: Firms jointly decide whether or not to locate in the same or different countries in Stage 0. Each firm sets up one plant and uses it to serve both its domestic and foreign markets. For simplicity, we assume that if firms decide to locate in the same countries, they choose country 1.[15]

Stage 1[Collaboration decision]: Identical to Stage 1 in the original model, where firms jointly determine whether or not to collaborate in designing a platform of their products.

Stage 2 [Product market competition]: Identical to Stage 2 in the original model, where Bertrand competition between the two firms takes place.

line and Toyota Production System (TPS). This is one of the longest running competitor collaborations of all. (http://www.industryweek.com/ReadArticle.aspx?ArticleID=10164)

[13] Additionally, Hamel (1991, p.86) points out that collaborators also benefit from each other by 'internalizing a partner's skill'. In an unsuccessful alliance, the party which learns aggressively as much as possible benefits more than its partner even if a collapse of the alliance beckons given that both have made an equal investment of some form or another. The most attractive resources to internalize are leading edge technology and management techniques.

[14] http://www.eetimes.com/story/OEG20030117S0029

[15] By symmetry of the model, the equilibria prices, quantities, produts and welfares will be the same if both firms choose to locate in country 2.

4.2. Analysis

As in the previous section, we consider the symmetric Subgame Perfect Nash Equilibria (SPNE) of Stage 2 subgames, and characterize an equilibrium of the entire game. We consider an equilibrium in which the two manufacturers jointly make decisions concerning the location and collaboration at Stage 0 and 1 respectively, so that each firm's profit in the subsequent symmetric SPNE outcome is maximized. In this setting, there are four Stage 2 subgames, two in both the same location and different location subgames.

Without the need to locate in the same countries when collaborating, firms always choose to locate in different countries given the same collaboration decision. By locating apart, trade cost protects firm i against its foreign competitor. Increasing trade cost reduces firm i's profitability in its export market but allows it to charge a higher domestic price and increase domestic quantities sold. On the contrary, when firms are located in the same countries, trade cost increases both firms' foreign prices and reduces their foreign profitabilities without any effect on domestic prices and quantities. This implies that both of the different countries subgames (collaboration and non-collaboration subgames) strictly dominate their same countries subgames counterparts.

In this extended model, we consider a case where communication is extremely costly and the only way to collaborate is to locate in the same countries. In this framework firms either locate in the same countries and collaborate or locate in different countries and not collaborate.

In stage 2, firm $i = 1, 2$ chooses p_{ij} to maximise the variable profit function from selling in country $j = 1, 2$. The maximisation problem when firms locate in the same countries (country 1) leads to

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

and

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

Because both firms supply in both countries, firm i's total profit in each stage 2 payoffs are given by

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

where we introduce the superscript S and D to denote the same and different countries subgames respectively.[16] Because firms only collaborate if they choose to locate in the same countries, we have

$$\pi_i^S(\gamma, t) = \pi_i^S(\gamma_0 + x, t). \tag{4..4}$$

Also, firms do not collaborate if they choose to locate in different countries, we redefine the loss function as

$$L(\gamma_0, x, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t). \tag{4..5}$$

[16]The payoff when firms locate in different countries and not collaboration calculated previously becomes $\pi_i^D(\gamma_0, t)$

As in the previous section, we make assumptions 1 and 2.[17] Because the loss function does not only include loss from collaboration but also loss from locating in the same countries. This means that when the loss in product distinctiveness from collaboration is close to 0, the loss function is greater than 0 if trade cost is positive. For simplicity in analysing the extended model, we impose assumption 3:

Assumption 3: $\frac{F}{2} > L(\gamma_0, 0, t)$.

The model requires that fixed cost saving from collaboration must be higher than the loss function where the loss in product distinctiveness from collaboration is 0. More precisely, the loss from collaboration needs to be higher than the loss from locating in the same countries. Clearly, without this requirement on fixed cost, firms might find it unprofitable to collaborate even when the loss in product distinctiveness is 0. This assmption ensures the possibility of collaboration in SPNE.

4.3. When does firm i collaborate?

Proposition 6 *There exist a function $x^*(t)$ such that firms 1 and 2 collaborate at Stage 1 in the unique equilibrium outcome if and only if $x \leq x^*(t)$, where $x \in (0, 1-\gamma_0)$ and $t \in [0, \bar{t})$.*

In the extended model, the loss function captures two effects. The first refers to the loss from collaboration. This is the loss in profits because firms loose product distinctiveness from collaboration. The second refers to the loss from locating in the same countries. Because firms have to locate in the same countries if they collaborate, firms forgo the benefit of trade protection in their domestic market meaning that they are no longer produce in the presence of cost asymmetry. We have proven in the appendix that $\pi_i^D(\gamma_0, t) \geq \pi_i^S(\gamma_0, t)$ and $\pi_i^D(\gamma_0 + x, t) \geq \pi_i^S(\gamma_0 + x, t)$ holds for any given $\gamma_0 \in (0,1)$, $x \in (0, 1-\gamma_0)$, and $t \in [0, \bar{t})$.

In comparison to the previous model, we find that for any $t \in (0, \bar{t})$, the loss function in the extended model is strictly higher than the loss function in the standard model ($\pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t) > \pi_i^D(\gamma_0, t) - \pi_i^D(\gamma_0 + x, t)$). Moreover, when trade cost is 0, the loss function in both models are the same ($\pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t) = \pi_i^D(\gamma_0, t) - \pi_i^D(\gamma_0 + x, t)$). The presence of Assmption 3 ensures that for any given trade protection, there is always a possibility for collaboration.

We find that the loss function $L(\gamma_0, x, t) = \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t)$ is increasing in x for all $x \in (0, 1-\gamma_0)$, i.e. $\frac{dL(\gamma_0,x,t)}{dx} > 0$. Because cost savings $\frac{F}{2}$ is not exogenously given and $F > 2L(\gamma_0, 0, t)$ from assumption 3, firms 1 and 2 choose to collaborate when x is relatively small. Analogous to Proposition 2, firms collaborate if $x \in (0, x^*(t))$.

4.4. How does trade cost effect collaboration?

Here, we find that the effect of trade cost on firms' collaboration decision is ambiguous. To investigate the net effect of trade cost on collaboration decision, we totally differentiate $L(\gamma_0, x^*(t), t) = \frac{F}{2}$ with respect to t and rearranging to obtain

$$\frac{dx^*(t)}{dt} = -\left.\frac{\frac{\partial L(\gamma_0,x,t)}{\partial t}}{\frac{\partial L(\gamma_0,x,t)}{\partial x}}\right|_{x=x^*(t)} \tag{4..6}$$

[17] The value of t where firms do not export in the same location and collaboration subgame is $t = a$.Therefore, we continue to impose assumption 2 since $\frac{1}{2-\gamma^2}\left(2a - a\gamma - a\gamma^2\right) < a$.

where $\frac{\partial L(\gamma_0,x,t)}{\partial t} = \frac{\partial \pi_i^D(\gamma_0,t)}{\partial t} - \frac{\partial \pi_i^S(\gamma_0+x,t)}{\partial t}$. From the previous proposition, $\frac{dL(\gamma_0,x,t)}{dx} > 0$ for all $x \in (0, 1-\gamma_0)$ and $t \in [0, \bar{t})$. Thus, the effect of trade cost on $x^*(t)$ depends on the sign of $\frac{\partial L(\gamma_0,x,t)}{\partial t}$. We find that $\frac{\partial \pi_i^S(\gamma_0+x,t)}{\partial t} < 0$ for $\gamma_0 \in (0,1)$, $x \in (0, 1-\gamma_0)$ and $t \in [0, \bar{t})$ since firms' profits in their foreign country always declines with trade cost when they locate in the same countries. The net effect of t on the loss function depends on the sign and magnitute of $\frac{\partial \pi_i^D(\gamma_0,t)}{\partial t}$. This is captured in the next Lemma.

Lemma 5 *For all $t \in (0, \bar{t})$, there exist $\hat{x}(\gamma_0, t) \in (0, 1-\gamma_0)$ such that the loss function is increasing in t for all $x < \hat{x}(\gamma_0, t)$. That is, $\frac{\partial \pi_i^D(\gamma_0,t)}{\partial t} - \frac{\partial \pi_i^S(\gamma_0+x,t)}{\partial t} > 0$ for all $x < \hat{x}(\gamma_0, t)$.*

This Lemma indicates that there exist x small enough such that the loss function is increasing in t for all $t \in (0, \bar{t})$. The finding here is different to the standard model when higher trade cost only reduces the loss function. The effect of trade cost on firms' collaboration decision is summarized in the next proposition.

Proposition 7 *The effect of trade cost on collaboration decision is ambiguous. Specifically, for all $t \in (0, \bar{t})$, there exist $\hat{\gamma}_0 \in (0,1)$ such that:*
(i) if $\gamma_0 > \hat{\gamma}_0$, $\frac{dx^*(t)}{dt} < 0$,
(ii) if $\gamma_0 < \hat{\gamma}_0$, there exist $\hat{F}(\gamma, t)$ such that $\frac{dx^*(t)}{dt} < (>) 0$ if $F < (>) \hat{F}(\gamma, t)$.

The first property in this proposition implies that for all if firms' degree of product distinctiveness is sufficiently low, for $\gamma_0 > \hat{\gamma}_0$, we find that higher trade cost always increases the loss from collaboration function for all possible loss in product distinctiveness from collaboration $x \in (0, 1-\gamma_0)$. Hence, given any value of fixed cost saving within the constraint of assumptions 1 and 3, higher trade cost reduces firms' incentive to collaborate. Moreover, the parameter of x where collaboration is profitable reduces from $x^*(t_0)$ to $x^*(t_1)$, where $x^*(t_1) < x^*(t_0)$.

The second property in this proposition implies that when $\gamma_0 < \hat{\gamma}_0$, depending on the value of fixed cost saving F, higher trade cost could increase or decrease firms' incentive to collaborate.

On the one hand, the previous Lemma indicates that there exist $x < \hat{x}(\gamma_0, t)$ when any increase in trade cost increases the loss from collaboration for all $t \in (0, \bar{t})$. This implies that in equilibrium, we can choose a value of fixed cost small enough such that $x^*(t) \in (0, \hat{x}(\gamma_0, t))$ to get $\left.\frac{\partial L(\gamma_0,x,t)}{\partial t}\right|_{x=x^*(t)} > 0$. This means that in equilibrium higher trade cost reduces the parameter of x where collaboration is more profitable from $x^*(t_0)$ to $x^*(t_1)$, where $x^*(t_1) < x^*(t_0)$. On the other hand if $x > \hat{x}(\gamma_0, t)$, any increase in trade cost decreases the loss from collaboration for all $t \in (0, \bar{t})$. This implies that in equilibrium, we can choose a value of fixed cost large enough such that $x^*(t) \in (\hat{x}(\gamma_0, t), 1-\gamma_0)$. This finding is analogous to the standard model where we obtain $\frac{dx^*(t)}{dt} < 0$ in equilibrium. Thus, higher trade cost increases the parameter of x where firms find it profitable to collaborate from $x^*(t_0)$ to $x^*(t_1)$, where $x^*(t_0) < x^*(t_1)$.

Hence, we find that the effect of increasing trade cost on collaboration decision is ambiguous.

4.5. Effects of competitor collaboration on Welfare

In the extended model, welfare in countries 1 and 2 are not symmetric. In the same location and collaboration subgame, an increase in trade cost does not effect prices, consumers and welfare in country 1 but raises prices, lowers quantities and reduces welfare in country 2. This section studies the effect of a change in trade cost on firms' location and collaboration decisions and welfare of aggregate consumers in countries 1 and 2 - as opposed to the previous section where we only considered welfare in one countries.

Similar to the findings in the previous section, we find that contrary to the standard intuition that trade cost has adverse effects on consumers, higher trade cost could in fact make some consumers better off when higher trade cost encourages or discourages collaboration. Moreover, we find that for any given trade cost, consumer maybe better off if firms switch from collaboration to no collaboration.

Lemma 6 *Let $CS^S(\gamma, t)$ and $CS^D(\gamma, t)$ represents the consumer surplus of the representative consumers in country 1 and 2 in the same location and collaborate subgame, and different location and not collaborate subgame respectively. Consumer surplus when firms locate in the same country is decreasing in t for all $t \in [0, \bar{t})$ and increasing in γ for all $\gamma \in (0, 1)$. More formally:*
((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 $\gamma \in (0, 1)$.

Similar to Lemma 4, we find that consumer surplus when both firms locate in the same country is decreasing in t and increasing in γ. Here, trade cost affects consumer in country 1 and 2 differently. When both firms are located in country 1, higher trade cost does not affect consumers in country 1 but reduces consumer surplus in country 2 because both firms' prices increases as a result of higher trade cost. The reduction in consumer surplus in country 2 as a result of higher trade cost is higher relative to when firms are located in different countries. This is because consumer no longer have the option of buying from the cheaper domestic producer. Here, we can no conclude from property 2 in this Lemma that collaboration always benefit consumer since firms switch from different country to same country when they decide to collaborate. In this game, the functional form of consumer surplus changes as firms switch between collaboration subgames.

The next Lemma compares consumer surplus when firms are located in different countries to the consumer surplus when firms are located in the same countries, given the same collaboration decision.

Lemma 7 *Consumer prefers firms to locate in different countries than same countries ceteris paribus. i.e. $CS^D(\gamma, t) - CS^S(\gamma, t) = t^2 \frac{\gamma^3}{(1-\gamma^2)(\gamma^2-4)^2} > 0$ for $t \in (0, \bar{t})$ and $\gamma \in (0, 1)$.*

This Lemma states that given the same collaboration decision and the presence of trade cost, the aggregate consumer surplus in countries 1 and 2 is higher when firms are located in different countries.

Here, trade cost affects consumers in country 1 and 2 differently. Because firms locate in country 1 when they choose to locate in the same countries, consumer in country 1 always prefer firms to locate in the same countries when trade cost is positive. This is because both firms become domestic producers in country 1 and trade cost does not affect prices and quantities sold. Thus, the differences between consumer surplus when firms locate in different and the same country for consumer in country 1 is always negative.

On the other hand, consumer in country 2 prefers firms to locate in different countries. If firms choose to locate in different countries, country 2 does not have any domestic producer and they do not have the option of buying from the cheaper local producer to avoid paying trade cost. Hence, consumer in country 2 prefers to have one local producer than none. The differences between consumer surplus when firms locate in different and the same country for consumer in country 2 is always positive.

We find that the latter effect dominates the former and hence, aggregate welfare is higher when firms locate in different countries.

Proposition 8 *For any given trade cost $t \in (0, \bar{t})$, consumer maybe better off if firms switch from collaboration to no collaboration when x is small.*

This proposition suggests that for any positive trade cost, consumers may be better off when firms switch from collaboration to no collaboration because firms switch their location decision. When the loss in product distinctiveness from collaboration is small, firms find it more profitable to collaborate. However, by choosing to collaborate they must locate in the same countries. Because the loss in product distinctiveness is small, the positive effect on consumer surplus (the price effect) is also small. We find that the loss in consumer surplus when firms locate in the same countries may dominate the price effect from collaboration and welfare can be improved if firms do not collaborate when it is profitable to do so.

To analyse the change in consumer surplus as a result of higher trade cost, we define the equilibrium consumer surplus in SPNE for any given t,

$$CS^*(t) = \begin{cases} CS^S(\gamma_0 + x, t) \text{ if } x \leq x^*(t) \\ CS^D(\gamma_0, t) \text{ if } x > x^*(t). \end{cases} \tag{4..7}$$

Similaryly to the standard model, we find that contrary to the conventional understanding that trade cost adversely affect welfare, higher trade cost can be welfare improving. In this model, we find that an increase in trade cost can induce firm to switch from collaboration to no collaboration and vice versa in SPNE. We show that under both circumstances, higher trade cost can be welfare improving.

Proposition 9 *By choosing t_0 and t_1 appropriately, an increase in trade cost from t_0 to t_1 can increase consumer surplus under both circumstances when trade cost encourages or discourages competitor collaboration. That is, we can choose appropriate t_0 and t_1 such that $CS^*(t_0) < CS^*(t_1)$ for both $x^*(t_0) < x^*(t_1)$ and $x^*(t_0) > x^*(t_1)$.*

Logic behind the result is as follows. Collaboration intensifies the competition between the two firms, which in turn reduces the share of total surplus captured by the two manufacturers as their aggregate profit. However, the level of their aggregate profit is higher under collaboration if the cost saving outweights the loss from collaboration. The establishment of trade cost could be viewed as an anticompetitive activity that results in higher consumer surplus when accompanied by collaboration, because it induces firms to collaborate at the expense of reduced product variety but lower price.

We found in the previous proposition that there exist x such that an increase in t from t_0 to t_1 can increase or decrease firms' incentive to collaborate. This proposition suggest that under both circumstances, we can pick t_0 and t_1 such that consumer surplus is higher in equilibrium.

Consider a status quo when firms locate in different countries and not collaborate. From Proposition 7, we know that firms switch from no collaboration to collaboration when trade cost increase and $x \in (x^*(t_0), x^*(t_1)]$ $(x^*(t_0) < x^*(t_1))$. This change in equilibrium outcome means that firms are switching both their location and collaboration decision in equilibrium. By choosing to locate in the same countries, welfare is now strictly lower as discussed in Lemma 8. On the other hand, higher trade cost reduces the loss from collaboration and induces firms to collaborate. The price effect on welfare as a result of collaboration increases aggregate welfare because collaboration intensifies competition. We find taht the latter effect dominates the former when t_0 and the change in t_0 to t_1 is small.

Also, from Proposition 7, higher trade cost can discourage competitor collaboration when $\gamma_0 > \hat{\gamma}_0$ and $F < \hat{F}(\gamma, t)$ if $\gamma_0 < \hat{\gamma}_0$.

Here, an increas in t from t_0 to t_1 induces firms to switch from collaboration to no collaboration when $x \in [x^*(t_1), x^*(t_0))$ $(x^*(t_1) < x^*(t_0))$. We find that when the change in t_0 to t_1 is small, the loss in welfare as a result of lower competition can be smaller than the gain in welfare as firms switch to locate in different countries. Hence, consumer can be better off even when an increase in trade cost discourages competitor collaboration.

Similarly to the previous model, we find that in the context of competitor collaboration, the establishment of trade cost could be viewed as an anticompetitive activity that results in higher consumer surplus when accompanied by collaboration because it induces firms to collaborate at the expense of reduced product variety but lower price. However, we also find that when when trade cost discourages collaboration, welfare can be improving because firms locate in different countries.

5. Discussion of Results

In the last two decades, the world has witnessed dramatic delines in transportation cost, trade barriers, and communication cost; advancement in technology, mobility of technology and capital; and spread of economic process and global consumer culture. Electronic commerce, due to recent advances in information technology (IT revolution), is substantially changing the nature of how people communicate from different parts of the world. The impact of communication cost on firms' daily decision making has significantly declined with increasing public investments on scientific infrastructure that supports the ever-changing technological advancements. Communication between firms from different parts of the world has become easier and more economical. For example, installments of fibre-optic network that is connected to 'every home and business' for 'real broadband' reduces both communication cost and communication time, allowing firms to substitute communication for travel.[18] Moreover, by applying Internet-based information systems (IBIS) systems like the teleconference system or group decision support system (GDSS), enterprises can reduce their communication cost, overcome regional communication problems, and enhance the efficiency of managerial decision making (Aiken et al., 1994; Chen et al., 1998).

Our finding has contributed to the important recent reduction in transportation cost, trade barriers and communication cost in the world trend by proposing a theoretical framework for analysis. We have found that when communication cost is small, higher trade barriers encourages collaboration between firms. Moreover, when cost asymmetry resulting from trade barrier is high, firms receive an additional gain from collaboration to their fixed cost savings. On the other hand, when communication cost is high, we found that increasing trade cost could discourage collaboration decision if the loss in product distinctiveness from collaboration is small.

[18] http://www.abc.net.au/worldtoday/content/2007/s1948651.htm and http://www.axia.com/about_axia/sets_our_networks_

We have proven that firms always choose to locate in different countries if they can afford the communication cost. This finding is consistent with location evidences in the real world where firms collaborate in designing common parts but locate in different countries.

Under both communication cost game, we found that an increase in trade cost always reduces total welfare if firms' does not switch their collaboration decision. Nevertheless, we found that for any given trade cost, there exist an increase in trade cost and loss in product distinctiveness from collaboration such that consumer surplus increases. Contrary to the orthodox believe that trade cost reduces welfare, we find that an increase in trade cost can be welfare improving with the possibility of collaboration.

6. Conclusion

This paper first develops a model to demonstrate how trade costs and communication costs effect collaboration and location decisions of firms producing differentiated products. This paper explores the relationship between the trade-off from competitor collaboration and trade costs which in turn provides insight into the formation as well as welfare consequences of competitor collaboration - as a form of strategic alliances (SAs) - in the international context. This paper focuses on the investment of designing and development of a product a kind of collaboration among competing firms. We consider a case where SAs is not anticompetitive. The objective of this paper is to conduct a formal analysis on the effects of international competitor collaborations on competition and welfare. We consider two models of extreme communication costs. The first model consider a case where communication cost is close to 0. The analytical framework with the model in absence of communication is based upon the "reciprocal dumping" model of Brander and Krugman (1983). The main focus is on the effect of transportation cost that allows two firms in different countries to enter each other's market. Trade cost also affect firms decision to collaborate. In this kind of setting, each firm has incentives to export its product to the other market. The second analysis incorporates communication cost in the competitor collaborations game. To capture the role of communication costs we develop a model where communication is extremely costly and hence firms, if engage in competitor collaboration have to locate in the same country. The only way to establish SAs is when firms are located closely to each other. This is because communication is easier with closer locations. We explore how transportation cost effects firm's collaborating decision and conduct welfare analyses. We found that under both extreme values of communication cost, with the possibility of collaboration, higher trade cost will induce firms to collaborate to gain higher profits. This change of collaboration decision can possibly lead to higher total welfare as a result of higher trade cost.

7. Appendix

A Proof of Lemma 1

Recalling the loss from collaboration function,

$$L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t)$$

For for low t, we have $\left.\frac{\partial \pi_i(\gamma_0,x,t)}{\partial \gamma_0}\right|_{t=0} = 4a^2 \frac{(1-\gamma_0(1-\gamma_0))}{(\gamma_0+1)^2(\gamma_0-2)^3} < 0 \forall \gamma_0 \in (0,1)$. This implies $\pi_i(\gamma_0, t) > \pi_i(\gamma_0 + x, t)$, at the free trade point, we get a result where there exist loss from collaboration as $L(\gamma_0, x, t) > 0$.

For high t, we obtain $\left.\frac{\partial \pi_i(\gamma_0,x,t)}{\partial \gamma_0}\right|_{t=\bar{t}}$[19] $= 2a^2\gamma_0(\gamma_0 - 1)\frac{\gamma_0+1}{(\gamma_0^2-4)(\gamma_0^2-2)^2} > 0$. This implies $\pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t) < 0$ and there exist negative loss from collaboration because $L(\gamma_0, x, t) < 0$. We found $\frac{\partial^2 \pi_i(\gamma_0,t)}{\partial \gamma_0 \partial t} = \frac{2}{(\gamma_0^2-1)^2(4-\gamma_0^2)^3}(At + B) > 0$ because $A > 0$ and $B > 0$ for $\gamma_0 \in (0, 1)$. Thus there exist a unique solution $\frac{\partial \pi_i(\gamma_0,t)}{\partial \gamma_0} = 0$ at $\tilde{t}$ where $\tilde{t} < \bar{t}$ and

$$\tilde{t} = a\frac{1-\gamma_0}{12\gamma_0-7\gamma_0^3+2\gamma_0^5-\gamma_0^7}\left(\begin{array}{c} 4\gamma_0 + 2\gamma_0^2 - 5\gamma_0^3 + 2\gamma_0^4 + 4\gamma_0^5 + \gamma_0^6 \\ +\gamma\sqrt{-(\gamma_0-2)^3(\gamma_0+2)^3(-\gamma_0+\gamma^2+1)(\gamma_0+\gamma_0^2+1)} \\ +\sqrt{-(\gamma_0-2)^3(\gamma_0+2)^3(-\gamma_0+\gamma_0^2+1)(\gamma_0+\gamma_0^2+1)} - 8 \end{array}\right).$$

B Proof of Lemma 2 and Proposition 2

Let $L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t)$ where $\pi_i(\gamma_0, t) = \pi_{i1}(\gamma_0, t) + \pi_{i2}(\gamma_0, t)$ and $\pi_i(\gamma_0 + x, t) \equiv \pi_{i1}(\gamma_0 + x, t) + \pi_{i2}(\gamma_0 + x, t)$. Define

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

Collaboration occurs if and only if $h(\gamma_0, x, t, F) \geq 0$. Let $h(\gamma_0, x^*(t), t, F) = 0$ where $x^*(t) \in (0, 1 - \gamma_0)$. Now note that

(i) For $x = 0$, $\pi(\gamma_0, t) = \pi(\gamma_0 + x, t)$ which implies $L(\gamma_0, x, t) = 0$ and consequently $h(\gamma_0, 0, t, F) = \frac{F}{2} > 0$.

(ii) If $t < \tilde{t}$, we have $\frac{dh(\gamma_0,x,t,F)}{dx} = -\frac{dL(\gamma_0,x,t)}{dx} < 0$ for all $x \in (0, 1 - \gamma_0)$. However, if $\tilde{t} \leq t < \bar{t}$, we have $\frac{dh(\gamma_0,x,t,F)}{dx} = -\frac{dL(\gamma_0,x,t)}{dx} \geq 0$ for all $x \in (0, 1 - \gamma_0)$,

(iii) For $t < \tilde{t}$, we have two possible values of $h(\gamma_0, \breve{x}, t, F)$ at $\breve{x} = 1 - \gamma_0$:

(a) If $\breve{x} = 1 - \gamma_0$ implies $\pi_i(\gamma_0 + \breve{x}, t) < \frac{F}{2}$, there must be $\tilde{x}(t)$ such that $\pi_i(\gamma_0 + \tilde{x}(t), t) = \frac{F}{2}$. By Assumption 1, $F < \min\{\pi_i(\gamma_0, t), 2\pi_i(\gamma_0 + x, t)\} = F'$, we have $\pi_i(\gamma_0, t) - F > 0$. Hence at $\tilde{x}(t)$,

[19] We use $\bar{t}$ to denote high t. This is the value of t such that firm 2 cease production (in Case 3) and $\bar{t} = \frac{1}{2-\gamma^2}\left(2a - a\gamma^2 - a\gamma\right)$.

$$\begin{aligned} h(\gamma_0, \tilde{x}(t), t, F) &= \frac{F}{2} - [\pi_i(\gamma_0, t) - \pi_i(\gamma_0 + \tilde{x}(t), t)] \\ &= \frac{F}{2} - [\pi_i(\gamma_0, t) - \frac{F}{2}] \\ &= F - \pi_i(\gamma_0, t) \\ &< 0. \end{aligned}$$

where equalities are self explanatory and the inequality follows from above. There must exist a unique number $x^*(t) \in (0, \tilde{x}(t))$ such that $h(\gamma_0, x, t, F) \geq 0$. *Q.E.D.*

(b) If $\breve{x} = 1 - \gamma_0$ implies $\pi_i(\gamma_0 + \breve{x}, t) \geq \frac{F}{2}$, then, $\pi_i(\gamma_0 + \breve{x}, t) + \frac{F}{2} = F'' \geq F$. At $\breve{x}$, we have

$$\begin{aligned} h(\gamma_0, \breve{x}, t, F) &= \frac{F}{2} - [\pi_i(\gamma_0, t) - \pi_i(\gamma_0 + \breve{x}(t), t)] \\ &= F'' - \pi_i(\gamma_0, t). \end{aligned}$$

When $F'' > F$, it is possible that $F'' - \pi_i(\gamma_0, t)$ can be positive or negative. If $F'' - \pi_i(\gamma_0, t) < 0$ then $h(\gamma_0, \breve{x}, t, F) < 0$. Here, we obtain the same result as in (a). However, if $F'' - \pi_i(\gamma_0, t) > 0$, then $h(\gamma_0, \breve{x}, t, F) > 0$ and $x^*(t) \notin (0, 1 - \gamma_0)$. Here we find that firms always collaborate for all $x \in (0, 1 - \gamma_0)$. *Q.E.D.*

For $\tilde{t} \leq t < \bar{t}$, we have one possibility for the value of $h(\gamma_0, \breve{x}, t, F)$ at $\breve{x} = 1 - \gamma_0$:

c. For $\tilde{t} \leq t < \bar{t}$, $\frac{dh(\gamma_0, x, t, F)}{dx} = -\frac{dL(\gamma_0, x, t)}{dx} \geq 0$ and hence, $x^*(t)$ such that $h(\gamma_0, x^*(t), t, F) = 0$ does not exist. At $\breve{x} = 1 - \gamma_0$, $h(\gamma_0, \breve{x}, t, F) > 0$. By continuity, firms collaborate for all $x \in (0, 1 - \gamma_0)$. *Q.E.D.*

For all the cases discussed, we must have $h(\gamma_0, x, t, F) \geq 0$ if and only if $x \leq x^*(t) \in (0, 1 - \gamma_0)$.

C Proof of Lemma 3 and Proposition 3

Recalling $h(\gamma_0, x, t, F) \equiv \frac{F}{2} - (\pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t))$. Since $h(\gamma_0, x^*(t), t, F) \equiv 0$, we have $L(\gamma_0, x^*(t), t) = \frac{F}{2}$. Because $\frac{\partial L(\gamma_0, x, t)}{\partial x} \neq 0$ we can apply implicit differentiation theorem to total differentiate $L(\gamma_0, x^*(t), t) = \frac{F}{2}$ with respect to t. By rearranging the derivative, we obtain

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

Given that $\frac{\partial \pi_i(\gamma_0 + x, t)}{\partial x} < 0$ for all $t \in [0, \tilde{t})$, we have for all (γ_0, x, t), we have $\frac{dL(\gamma_0, x, t)}{dx} > 0 \forall t \in [0, \tilde{t})$.

To determine $\frac{\partial L(\gamma_0, x, t)}{\partial t}$, we write $L(\gamma_0, x, t) = \hat{A}t^2 + \hat{B}t + \hat{C}$ and hence, we have $\frac{dL(\gamma_0, x, t)}{dt} = 2\hat{A}t + \hat{B}$ where

$\hat{A} = (-\frac{\gamma_0^2}{(\gamma_0^2-1)(\gamma_0^2-4)^2} - \frac{(\gamma_0^2-2)^2}{(\gamma_0^2-1)(\gamma_0^2-4)^2} + \frac{(x+\gamma_0)^2}{((x+\gamma_0)^2-1)((x+\gamma_0)^2-4)^2} + \frac{((x+\gamma_0)^2-2)^2}{((x+\gamma_0)^2-1)((x+\gamma_0)^2-4)^2})$, $\hat{B} = (2a\frac{\gamma_0-1}{(\gamma_0+1)(\gamma_0-2)^2} - 2a\frac{x+\gamma_0-1}{(x+\gamma_0+1)(x+\gamma_0-2)^2})$, and $\hat{C} = 2a^2\frac{x+\gamma-1}{(x+\gamma+1)(x+\gamma-2)^2} + \frac{2}{(1-\gamma^2)(\gamma^2-4)^2}(a\gamma^2 + a\gamma - 2a)^2$.

For coefficient $\hat{A}$, $-\frac{\gamma_0^2}{(\gamma_0^2-1)(\gamma_0^2-4)^2} - \frac{(\gamma_0^2-2)^2}{(\gamma_0^2-1)(\gamma_0^2-4)^2}$ is increasing in γ_0, hence, $\hat{A} < 0$. For coefficient $\hat{B}$, $2a\frac{\gamma_0-1}{(\gamma_0+1)(\gamma_0-2)^2}$ is increasing in γ_0, thus, $\hat{B} < 0$.

Thus, $\hat{A} < 0$ and $\hat{B} < 0$ implies $\frac{\partial L(\gamma_0,x,t)}{\partial t} < 0$ for all $\gamma_0 \in (0,1)$ and $x \in (0, 1-\gamma_0)$. In equilibrium, $\frac{dL(\gamma_0,x,t)}{dx} > 0$ and $\frac{\partial L(\gamma_0,x,t)}{\partial t} < 0$, hence $\frac{dx^*(t)}{dt} > 0 \forall \gamma_0 \in (0,1)$, $x \in (0, 1-\gamma_0)$, and $t \in [0, \tilde{t})$. *Q.E.D.*

D Proof of Lemma 4

The consumer surplus function $CS_j(\gamma, t)$ can be written as

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

where $\check{A} = \frac{1}{2}\frac{3\gamma^2-4}{(\gamma^2-1)(\gamma^2-4)^2}$, $\check{B} = -\frac{a}{(\gamma+1)(\gamma-2)^2}$, and $\check{C} = \frac{a^2}{(\gamma+1)(\gamma-2)^2}$. By differentiating the consumer surplus function with respect to t, we can write $\frac{dCS_j(\gamma,t)}{dt} = 2\check{A}t + \check{B}$. Evaluating at $t = 0$, we obtain $\left.\frac{\partial CS_j(\gamma,t)}{\partial t}\right|_{t=0} = \check{B} < 0$ for all $\gamma \in (0,1)$. By evaluating at $\bar{t}$, the highest value of t where there exist loss from collaboration, we obtain $\left.\frac{\partial CS_j(\gamma,t)}{\partial t}\right|_{t=\bar{t}} = a\frac{\gamma}{(4-\gamma^2)(\gamma^2-2)} < 0$ for all $\gamma \in (0,1)$. Also $\frac{\partial^2 CS_j(\gamma,t)}{\partial t^2} = \check{A} > 0$ for all $\gamma \in (0,1]$ and hence $\frac{dCS_j(\gamma,t)}{dt} < 0$ for all $t \in [0, \tilde{t})$.

By differentiating the consumer surplus function with respect to γ, we have that

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

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

We obtain $\left.\frac{dCS_j(\gamma,t)}{d\gamma}\right|_{t=0} = \tilde{C} > 0$ for all $\gamma \in (0,1)$ and $\left.\frac{dCS_j(\gamma,t)}{d\gamma}\right|_{t=\bar{t}} = 3\gamma\frac{a^2}{(4-\gamma^2)(\gamma^2-2)^2} > 0$ for all $\gamma \in (0,1)$. Moreover, because $\tilde{B}^2 - 4\tilde{A}\tilde{C} = 9a^2\frac{\gamma^2}{(\gamma^2-1)^2(\gamma^2-4)^3} < 0$ there is no real roots and the solution $t \in [0, \tilde{t})$ satisfying $\frac{dCS_j(\gamma,t)}{d\gamma} = 0$ for any $\gamma \in (0,1)$ does not exist. Hence, $\frac{dCS_j(\gamma,t)}{d\gamma} > 0 \forall t \in [0, \bar{t})$.

E Proof of Proposition 4

Claim 1: For all $t_0 \in [0, \tilde{t})$, there exist $\delta > 0$ 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 not, then there exist $t_0 \in [0, \tilde{t})$ for all $\delta > 0$ and $x \in (0, 1-\gamma_0)$ such that $CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta) \leq CS_j(\gamma_0, t_0)$ which implies

$$\begin{aligned}
\lim_{\delta\to 0} CS_j(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta) &\leq \lim_{\delta\to 0} CS_j(\gamma_0, t_0) \\
CS_j(\gamma_0 + x^*(t_0), t_0) &\leq CS_j(\gamma_0, t_0).
\end{aligned}$$

Because $\frac{dCS_i(\gamma,t)}{d\gamma} > 0$, we cannot have $CS_i(\gamma_0 + x^*(t_0), t_0) \leq CS_i(\gamma_0, t_0)$. *Q.E.D.*

We can pick $t_1 = t_0 + \delta$ and $x = x^*(t_0 + \delta)$ such that $CS^*(t_1) = CS_i(\gamma_0 + x^*(t_0 + \delta), t_0 + \delta)$ and $CS^*(t_0) = CS_i(\gamma_0, t_0)$ such that $CS^*(t_1) > CS^*(t_0)$ *Q.E.D.*

F Proof of (CASE 3VS1)

If firms chose to collaborate, they will choose to locate in different countries and capitalise in their domestic market (they can charge higher price through price protection). Thus, CASE 1 will never be chosen in the equilibrium since it is dominated by CASE 3.

Let $L(\gamma_0, x, t) = \pi_i(\gamma_0 + x, t) - \pi_i(\gamma_0 + x, t) \equiv \pi^D(\gamma_0 + x, t) - \pi^S(\gamma_0 + x, t)$, where $\pi_i(\gamma_0 + x, t) \equiv \pi_{i1}(\gamma_0 + x, t) + \pi_{i2}(\gamma_0 + x, t)$ and $\pi_i(\gamma_0 + x, t) \equiv \pi_{i1}(\gamma_0 + x, 0) + \pi_{i2}(\gamma_0 + x, t)$. We have $L(\gamma_0, x, t) = 2t^2\gamma\frac{(\gamma^2-2)}{(\gamma^2-1)(\gamma^2-4)^2} > 0$ where $(\gamma = \gamma_0 + x)$ and $\gamma \in (0, 1)$.

G Proof of (CASE 4VS2)

If firms chose not to collaborate (No need to worry about communication cost since it is only incurred when they collaborate), they will choose to locate in different countries and capitalise in their domestic market (they can charge higher price through price protection). Thus, CASE 2 will never occur and it is dominated by CASE 4.

Let $L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + 0, t) \equiv \pi^D(\gamma_0, t) - \pi^S(\gamma_0, t)$, where $\pi_i(\gamma_0, t) \equiv \pi_{i1}(\gamma_0, t) + \pi_{i2}(\gamma_0, t)$ and $\pi_i(\gamma_0+0, t) \equiv \pi_{i1}(\gamma_0+0, 0) + \pi_{i2}(\gamma_0+0, t)$. We have $L(\gamma_0, x, t) = 2t^2\gamma_0\frac{\gamma_0^2-2}{(\gamma_0^2-1)\left(\gamma_0^2-4\right)^2}$ > 0 for all $\gamma_0 \in (0, 1)$. Thus, $\frac{dL(\gamma_0,x,t)}{dt} = 4t\gamma_0\frac{(\gamma_0^2-2)}{(\gamma_0^2-1)\left(\gamma_0^2-4\right)^2} > 0$ for all $\gamma_0 \in (0, 1)$.

H Proof of Proposition 7

Let $L(\gamma_0, x, t) = \pi_i(\gamma_0, t) - \pi_i(\gamma_0 + x, t) \equiv \pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + x, t)$. Define

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

Collaboration occurs if and only if $h(\gamma_0, x, t, F) \geq 0$.Now note that

(i) For $x = 0$, the condition $\pi_i^D(\gamma_0, t) > \pi_i^S(\gamma_0 + x, t)$ must hold since firm i' profit from locating in different countries is always higher than locating in the same countries. This implies $L(\gamma_0, 0, t) > 0$. By Assumption 3, $\frac{F}{2} > L(\gamma_0, 0, t)$, we must have $h(\gamma_0, 0, t, F) > 0$,

(ii) $\frac{\partial h(\gamma_0,x,t,F)}{\partial x} = -\frac{\partial L(\gamma_0,x,t)}{\partial x} < 0$ for all $t \in [0, \bar{t}), \gamma_0 \in (0, 1)$ and $x \in (0, 1 - \gamma_0)$ because $\left.\frac{\partial L(\gamma_0,x,t)}{\partial x}\right|_{t=0} = 4\frac{a^2}{(x+\gamma+1)^2(2-x-\gamma)^3}\left(1 + x^2 + 2x\gamma + \gamma^2 - x - \gamma\right) > 0$, $\left.\frac{\partial L(\gamma_0,x,t)}{\partial x}\right|_{t=\bar{t}} > 0$ and $\frac{\partial^2 L(\gamma_0,x,t)}{\partial x \partial t} = 4\frac{(a-t)}{(x+\gamma+1)^2(x+\gamma-2)^3}\left(1 + x^2 + 2x\gamma + \gamma^2 - \gamma - x\right) < 0$ for all $\gamma_0 \in (0, 1)$ and $x \in (0, 1 - \gamma_0)$,

(iii) We have $\pi_i(\gamma_0, t) > F > \frac{F}{2}$. Given $x = 1 - \gamma_0$, we have $\pi_i^S(\gamma_0 + x, t) \equiv 0 < \frac{F}{2}$. There exist $\tilde{x}$ such that $\pi_i^S(\gamma_0 + \tilde{x}, t) = \frac{F}{2}$. By Assumption 1, $F_i < Max\{\pi_i(\gamma_0, t), \pi_i(\gamma_0 + x, t)\} \equiv F'$, we have $\pi_i^D(\gamma_0, t) - F > 0$. At $\tilde{x}$, we have

$$\begin{aligned}
h(\gamma_0, \tilde{x}, t, F) &= \frac{F}{2} - [\pi_i^D(\gamma_0, t) - \pi_i^S(\gamma_0 + \tilde{x}, t)] \\
&= \frac{F}{2} - [\pi_i^D(\gamma_0, t) - \frac{F}{2}] \\
&= F - \pi_i^D(\gamma_0, t) \\
&< 0
\end{aligned}$$

where equalities are self explanatory and the inequality follows from above.

Thus $\frac{\partial L(\gamma_0,x,t)}{\partial x} > 0$ and $\frac{\partial h(\gamma_0,x,t,F)}{\partial x} < 0$. We find that there exists a unique number $x^*(t) \in (0,\tilde{x})$ such that $h(\gamma_0,x,t,F) \geq 0$. *Q.E.D.*

I Proof of Lemma 5 and Proposition 7

Recalling $h(\gamma_0,x,t,F) \equiv \frac{F}{2} - (\pi_i^D(\gamma_0,t) - \pi_i(\gamma_0^S + x,t))$. Since $h(\gamma_0,x^*(t),t,F) \equiv 0$, we have $L(\gamma_0,x^*(t),t) = \frac{F}{2}$. Totally differentiating with respect to t we obtain

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

We have $\frac{dL(\gamma_0,x,t)}{dx} > 0$ for all $t \in [0,\bar{t}), \gamma_0 \in (0,1)$ and $x \in (0,1-\gamma_0)$. To determine $\frac{\partial L(\gamma_0,x,t)}{\partial t}$, we write $L(\gamma_0,x,t) = \grave{A}t^2 + \grave{B}t + \grave{C}$ and hence, we have $\frac{dL(\gamma_0,x,t)}{dt} = 2\grave{A}t + \grave{B}$ where $\grave{A} = \left(\frac{4+\gamma_0^4-3\gamma_0^2}{(1-\gamma_0^2)(\gamma_0^2-4)^2} - \frac{1-x-\gamma_0}{(x+\gamma_0+1)(x+\gamma_0-2)^2}\right)$, $\grave{B} = \left(2a\frac{\gamma_0-1}{(\gamma_0+1)(\gamma_0-2)^2} - 2a\frac{x+\gamma_0-1}{(x+\gamma_0+1)(x+\gamma_0-2)^2}\right)$ and $\grave{C} = 2a^2\frac{x+\gamma-1}{(x+\gamma+1)(x+\gamma-2)^2} + \frac{2}{(1-\gamma^2)(\gamma^2-4)^2}\left(a\gamma^2 + a\gamma - 2a\right)^2$.

Proof of Proposition 7, property (i)

We have that

(a) $\lim\limits_{x\to 0}\frac{\partial L(\gamma_0,x,t)}{\partial t} = 4t\gamma_0\frac{(2-\gamma_0^2)}{(\gamma_0^2-4)^2(1-\gamma_0^2)} > 0$ from (Lemma 5), and

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

Using Scientific Workplace, we have that $\lim\limits_{x\to 1-\gamma_0}\frac{\partial L(\gamma_0,x,t)}{\partial t} > 0$ when γ_0 is close to 1 ($\gamma_0 > \hat{\gamma}_0$).This finding together with (a) and (b) imply property (i) of Proposition 7. Thus, for any $t > 0$, we have $\frac{\partial L(\gamma_0,x,t)}{\partial t} > 0$ for all $x \in (0,1-\gamma_0)$. In equilibrium $\frac{dx^*(t)}{dt} < 0$ and $x^*(t_1) < x^*(t_0)$. *Q.E.D.*

Proof of Proposition 7, property (ii)

From Lemma 5 we know that

(a) there exist $\hat{x}(\gamma_0,t)$ where $\left.\frac{\partial L(\gamma_0,x,t)}{\partial t}\right|_{x=\hat{x}(\gamma_0,t)} = 0$ such that $\frac{\partial L(\gamma_0,x,t)}{\partial t} > 0$ for all $x < \hat{x}(\gamma_0,t)$. Now consider $\gamma_0 < \hat{\gamma}_0$.From Lemma 5 we have $\lim\limits_{x\to 0}\frac{\partial L(\gamma_0,x,t)}{\partial t} = 4t\gamma_0\frac{(2-\gamma_0^2)}{(\gamma_0^2-4)^2(1-\gamma_0^2)} > 0$. Choose F small enough ($F < \hat{F}(\gamma,t)$) such that $x^*(t) < \hat{x}(\gamma_0,t)$. This implies that for any $t > 0$, we have $\frac{\partial L(\gamma_0,x,t)}{\partial t} > 0$ when $x^*(t) < \hat{x}(\gamma_0,t)$. In equilibrium $\frac{dx^*(t)}{dt} < 0$ and $x^*(t_1) < x^*(t_0)$. *Q.E.D.*

(b) there exist $\hat{x}(\gamma_0,t)$ such that $\frac{\partial L(\gamma_0,x,t)}{\partial t} < 0$ for all $x \in (\hat{x}(\gamma_0,t),1-\gamma_0)$. Choose F large enough ($F > \hat{F}(\gamma,t)$) such that $x^*(t) \in (\hat{x}(\gamma_0,t),1-\gamma_0)$. This implies that for any $t > 0$, we have $\frac{\partial L(\gamma_0,x,t)}{\partial t} > 0$ when $x^*(t) \in (\hat{x}(\gamma_0,t),1-\gamma_0)$. In equilibrium $\frac{dx^*(t)}{dt} > 0$ and $x^*(t_0) < x^*(t_1)$. *Q.E.D.*

J Proof of Lemma 6

In this game, consumer surplus in countries 1 and 2 are no longer symmetric because both firms 1 and 2 are located in country 1. 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. We study a comparative static of aggregate consumer surplus in both countries and trade cost. Let $CS^S(\gamma, t)$ denotes the aggregate consumer surplus of the representative consumers in countries 1 and 2 in the same location subgame. The superscript S represents the subgame where firms locate in the same countries. Aggregate consumer surplus can be written as

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

where $\acute{A} = \frac{1}{(\gamma+1)(\gamma-2)^2}$, $\acute{B} = \left(-2\frac{a}{(\gamma+1)(\gamma-2)^2}\right)$, and $\acute{C} = 2\frac{a^2}{(\gamma+1)(\gamma-2)^2}$. Consumer surplus is given by

$$CS(\gamma, t) = \begin{cases} CS(\gamma_0, t) \text{ without competitor collaboration} \\ CS(\gamma_0 + x, t) \text{ with competitor collaboration.} \end{cases}$$

We have,

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

Because $\frac{dCS(\gamma,t)}{dt} = -2\frac{a-t}{(\gamma+1)(\gamma-2)^2} < 0$, consumer surplus in the same countries subgame is decreasing in t for all $\gamma \in (0,1)$ and $t \in (0, \bar{t})$. Also, $\frac{dCS^S(\gamma,t)}{d\gamma} = 3\frac{\gamma}{(\gamma+1)^2(2-\gamma)^3}\left(2a^2 + t^2 - 2at\right) > 0$ for all $\gamma \in (0,1)$ and $t \in (0, \bar{t})$. Thus, γ and t has the same effect on consumer surplus in both the same and different location subgames.

K Proof of Lemma 7

Recall that the symmetric consumer surplus in country i when firms are located in different countries is $CS_i(\gamma, t)$. The aggregate consumer surplus when firms are located in country is thus given by $2CS_i(\gamma, t) = CS^D(\gamma, t)$ where the superscript D represents the subgame where firms locate in different countries.

The differences between consumer surplus in the different and same countries subgames are

$$CS^D(\gamma, t) - CS^S(\gamma, t) = t^2 \frac{\gamma^3}{(1-\gamma^2)(\gamma^2-4)^2} > 0$$

for all $t \in (0, \bar{t})$ and $\gamma \in (0,1)$.

Define

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

L Proof of Proposition 8

Claim: For any $t \in (0, \bar{t})$, there exist $\grave{x}(t) \in (0, 1-\gamma_0)$ such that $CS^D(\gamma_0, t) > CS^S(\gamma_0 + x, t)$ for all $x < \grave{x}(t)$.

Proof: By applying the limits

$$\begin{aligned}\lim_{x\to 0} CS^S(\gamma_0 + x, t) &< \lim_{x\to 0} CS^D(\gamma_0, t)\\ CS^S(\gamma_0, t) &< CS^D(\gamma_0, t).\end{aligned}$$

The proof follows from knowing that $CS^S(\gamma_0, t)$ is continuous and increasing in x. From Lemma 7 $CS^D(\gamma, t) - CS^S(\gamma, t) > 0$. Hence, there exist $x < \tilde{x}(t)$ such that $CS^S(\gamma_0, t) < CS^D(\gamma_0, t)$. *Q.E.D.*

M Proof of Proposition 9

Property ((i) of Proposition 9

Claim: There exists t_0 and t_1 satisfying $0 < t_0 < t_1 < \bar{t}$ such that $CS^*(t_1) > CS^*(t_0)$ when $x^*(t_1) > x^*(t_0)$.

Proof: By Proposition 7 we know that an increase in t can encourage collaboration. Let $\gamma_0 < \hat{\gamma}_0$ (where $\hat{\gamma}_0$ is defined in Proposition 7) and $F > \hat{F}(\gamma, t)$ so that $\frac{dx^*(t)}{dt} > 0$. Choose $t_0 = 0$, $t_1 = \delta$ and $x = x^*(\delta)$. Since $x^*(\delta) > x^*(0)$, then

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

Applying limits, we have $\lim_{\delta\to 0} CS^*(\delta) \to \lim_{\delta\to 0} CS^S(\gamma_0 + x^*(\delta), \delta) = CS^S(\gamma_0 + x^*(0), 0) = CS^D(\gamma_0 + x^*(0), 0)$. Because $\frac{dCS^D(\gamma,t)}{d\gamma} > 0$ (from Lemma 6), by continuity for appropriate values of t_0 and δ, an increase in trade cost from t_0 to t_1 can increase consumer surplus. That is $CS^*(t_1) > CS^*(t_0)$.

Property (ii) of Proposition 9

Claim: There exists t_0 and t_1 satisfying $0 < t_0 < t_1 < \bar{t}$ such that $CS^*(t_1) > CS^*(t_0)$ when $x^*(t_1) < x^*(t_0)$.

Proof: By Proposition 7 we know that an increase in t could discourage collaboration. Let $\gamma_0 > \hat{\gamma}_0$ (where $\hat{\gamma}_0$ is defined in Proposition 7). Choose arbitrary t_0 and $t_1 = t_0 + \delta$. By $x = x^*(t_0 + \delta)$ we know that $x^*(t_0 + \delta) < x^*(t_0)$.

Then

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

Taking limits we have $\lim_{\delta\to 0} CS^*(t_0+\delta) = CS^D(\gamma_0, t_0)$. Now, if $x^*(t_0)$ is small, then $CS^D(\gamma_0, t_0) > CS^S(\gamma_0 + x^*(t_0), t_0)$. As $F \to 0$, $x^*(t_0) \to 0$. So from Lemma 7, $CS^D(\gamma_0, t_0) - CS^S(\gamma_0, t_0) > 0$. By continuity, an increase in trade cost from appropriate value of t_0 to an appropriate value of t_1 can increase consumer surplus. The proof of $\gamma_0 < \hat{\gamma}_0$ and $F < \hat{F}(\gamma, t)$ can be applied analogously. *Q.E.D.*

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