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Firm-productivity and cross border merger*

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Abstract: We examine whether higher productivity of a foreign firm increases the incentive for a cross border merger, which is a dominant form of foreign direct investment in recent decades. In line with the empirical evidence, we show that the relationship between productivity of a foreign firm and cross border merger is mixed. We show that the market concentration effect plays an important role in determining the relationship and provide a rationale for a generally ignored empirical evidence showing a negative relationship between firm-productivity and cross border merger. Our results hold under both Cournot and Bertrand competition.

Key words: Cross border merger; Export; Foreign direct investment; Productivity

JEL Classifications: D42; D43; F12; F23; L12; L23

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Firm-productivity and cross border merger

1. Introduction

Following the trade and investment liberalization wave in the world economy, the number of firms involved in international trade and foreign direct investment has increased dramatically. Cross border mergers and greenfield foreign direct investments (FDIs) are two important ways through which many multinational firms serve foreign markets. One aspect that attracted attention in recent years is the relationship between firm-productivity and trade and investment. The seminal papers by Melitz (2003) and Bernard et al. (2003) examined whether higher productivity of a firm increases its incentive for export. Helpman et al. (2004) extended this line of research to analyse the relationship between firm-productivity, export and greenfield FDI. While these papers provide important insights, they did not look at cross border mergers, which became more popular than greenfield FDIs in recent decades (UNCTAD 2008, Neary, 2009).[1]

Nocke and Yeaple (2007: here-after NY) took a step to fill this gap by asking whether higher productivity of a foreign firm increases the incentive for a cross border merger. They considered the efficiency motive as the reason for a cross border merger and showed that if the firms differ in terms of mobile capabilities, the incentive for a cross border merger increased with a higher productivity of the foreign firm. Although NY provides important insights to the relationship between firm-productivity and cross border merger, their analysis may be more applicable for conglomerate mergers than for mergers among competing firms, since higher market

[1] As a result of the global economic crisis of 2008-09, both total FDI flow, and the level of cross border mergers decreased dramatically, but, recently they have tended to recover from the crisis episodes (UNCTAD 2013).

concentration following a merger, which is an important reason for mergers among competitors, is absent in NY.

Empirical evidence on firm-productivity and cross border merger is limited and provides mixed results. Trax (2011) finds that the most efficient UK firms choose cross border mergers over greenfield FDI in high intangibles industries, while she cannot find such evidence in the low intangibles sector. Raff et al. (2012) show that the most productive Japanese firms prefer greenfield FDIs over cross border mergers. Looking at the US firms, Nocke and Yeaple (2008) find that the higher productive firms prefer greenfield FDIs over cross border mergers.

Given this background, we provide an explanation for the mixed relationship between firm-productivity and cross border merger. More importantly, we provide a rationale for the empirically relevant negative relationship between firm-productivity and cross border merger. Our paper contributes to the theoretical literature on firm-productivity and merger by incorporating the market concentration effect of cross border mergers in a two-country oligopoly model.

Considering a Cournot duopoly and one-way trade, we first show that whether higher productivity of a foreign firm increases or decreases the incentive for a cross border merger depends on product differentiation (affecting the intensity of competition and the benefit from market concentration), and wage and productivity (affecting the marginal costs). We find a negative relationship between the foreign firm's productivity and the incentive for a cross border merger if the products are close substitutes, thus creating intense competition, and the foreign firm has a significantly lower marginal cost than the domestic firm. Otherwise, there is a positive relationship between the foreign firm's productivity and the incentive for a cross border merger. We then extend our analysis to show that our qualitative results hold under Cournot oligopoly, two-way trade and Bertrand competition.

Our paper complements and contrasts NY. In contrast to NY, we show that a lower productive foreign firm may have the higher incentive for a cross border merger. We also complement NY by showing that their result may hold for mergers among competitors.

The remainder of the paper is organized as follows. We review the related literature in Section 2. We describe the basic model and derive the results in Section 3. We discuss the implications of some of our assumptions in Section 4. Section 5 concludes. Many mathematical details are relegated to the Appendices.

2. Related Literature

Two recent developments in the literature on trade and investment are worth discussing.[2] The empirical literature in recent decades shows that firms selling abroad are different from firms not engaged in trade, and the decisions to participate in international markets are not random (Bernard and Jensen, 1999). Bernard and Jensen (1999) show that firms engaged in international trade are different in size, productivity, and capital intensity than those who operate only in the domestic markets.

Following these findings, the seminal papers by Melitz (2003) and Bernard et al. (2003) analyse theoretically the relationship between firm level productivity and export decisions of the firms. Their main finding is that more productive firms export while the less productive firms operate only domestically. Head and Ries (2003) and Helpman et al. (2004) extend this line of research by considering two ways to serve the foreign market – export and greenfield FDI – and show that the most productive firms undertake greenfield FDIs and the less productive firms export. Head and Ries (2003) also show that less productive firms may undertake greenfield FDIs

[2] See Markusen (2002) and Antràs and Yeaple (2014) for a survey.

in the presences of wage difference between the home and the host countries. There is a huge literature following these papers. Rather than trying to review that vast literature, we refer to Wager (2007) and Helpman (2011) for nice surveys of that literature.[3]

The second important development in the FDI literature is to consider the composition of FDIs. Although cross border merger is considered to be an important type of FDI (UNCTAD, 2008), the above-mentioned literature did not consider that aspect. There is another set of papers, such as Ferrett (2005), Bjorvatn (2004), Mattoo et al. (2004), Neary (2009), Spearot (2012), Diez and Spearot (2014), Davies et al. (2018) and Harms et al. (2018), which consider greenfield FDIs as well as cross border mergers to examine the internationalization decisions of firms.[4] These papers provide several important insights but, unlike our paper, they did not analyse the effects of firm-productivity on cross border mergers.

In NY, firm heterogeneity arises from the fact that firms have different types of capabilities: internationally mobile capabilities, as considered in our paper, and immobile capabilities.[5] If the firms differ in internationally mobile capabilities, which is relevant for our analysis, they show

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[3] Recently, Mukherjee (2017) shows that exporters may be less productive than non-exporters if the firms have non-constant marginal costs, thus providing a theoretical justification for some more recent empirical evidence showing that exporters may be less productive than non-exporters (Lu, 2010, Hallak and Sivadasan, 2013, Wagner, 2013 and 2014). Mukherjee and Marjit (2009) show that low productive firms may undertake greenfield FDI in the presence of wage bargaining between the labour union and management. Mukherjee (2010) shows that the preference function considered in Helpman et al. (2004) may be important for their result and a low productive firm may undertake greenfield FDI for a different consumer preference function. While Arnold and Hussinger (2010) confirm the findings of Helpman et al. (2004), Mrazova and Neary (2013) show that these findings only hold if a firm's variable cost of production and the transportation cost it faces are complementary. They also show that the result of Helpman et al. (2004) may not hold under different preference structures, where firms cannot be sorted based on their productivity in a way Helpman et al. (2004) proposed.

Ishikawa and Komoriya (2009 and 2010) show that domestic firms' incentives for serving the domestic market either from the domestic country or from a foreign country depend on the domestic and foreign marginal costs, trade costs, and the presence of fixed costs. Ghosh and Ishikawa (2018) show how the absorptive capacity of the host-country firm and IPR protection in the host country affect a foreign firm's incentive for greenfield FDI.

[4] One may look at Dixit (1984), Barros and Cabral (1994), Long and Vousden (1995), Head and Ries (1997), Richardson (1999), Roy et al. (1999) Horn and Levinsohn (2001), Collie (2003), Neary (2003, 2007), Straume (2003), Bjorvatn (2004), Mukherjee (2006), Saggi and Yildiz (2006), Qiu (2010) and Beladi and Mukherjee (2012) for some other papers on mergers in open economies. However, these papers did not address the question we analyse.

[5] While the production technology of a firm is considered as an example of mobile capabilities, local marketing experience or supply networks are associated with immobile capabilities.

that more productive foreign firms prefer cross border mergers over greenfield FDIs.[6] NY assume that a cross border merger exploits complementarities by combining firm-specific capabilities, thus considering efficiency gain as the motive for a merger. However, they do not focus on the market concentration effect, which is our focus. We show that the relationship between the incentive for a cross border merger and the productivity of a foreign firm is non-monotonic, and a low productive foreign firm may prefer cross border merger if the firms differ in internationally mobile capabilities.

There is another paper by Nocke and Yeaple (2008) where they show that high productive firms prefer greenfield FDIs over cross border mergers. However, their reason is different from ours. They consider a model of "vertical FDI" with complementary "headquarter input" and "production input". Merger in their paper means acquisition of a higher productive production division by a firm with a lower productive production division. Hence, merger in their paper allows the acquirer to enjoy a cost reduction by taking over a higher productive production division and because the target production division is efficient than the acquirer, the acquirer's benefit from cost reduction is independent of its productivity. Since the acquirer's no-merger profit increases with its productivity, the acquirer's gain from merger decreases with its own productivity, and a higher productive acquirer prefers greenfield FDI than a cross border merger. It is worth noting that if the wage rates are the same in both countries, thus eliminating the benefit from greenfield FDI, cross border merger is always the preferable strategy in their paper.[7]

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[6] They show that the less efficient foreign firms are engaged in cross border mergers when firms differ in terms of internationally immobile capabilities.

[7] There are other papers on firm-productivity and foreign direct investments, but the focus of those papers is different from ours. Röller (2001), Stiebale and Rieze (2011) and Stiebale (2013) show the effects of foreign acquisition on a firm's innovation. Stiebale and Trax (2011) show the effects of cross border mergers on domestic productivity and the acquiring firms' domestic performance. Balsvik and Haller (2011) show the effects of foreign direct investment on host-country productivity.

There are some important differences between our paper and Nocke and Yeaple (2008). First, the acquirer in our analysis (whose productivity is the point of focus) is more productive compared to the target firm. Hence, merger in our paper creates different effects from theirs. Second, unlike them, merger in our paper does not create cost synergy. Third, we consider "horizontal FDI" with no fragmentation of production. While our result is due to the market concentration effect following a merger, the benefit from cost synergy is the driving force for their result. Finally, by considering fragmentation of production between "headquarter" and "production division" they consider acquisition of a production division only, while we consider acquisition of the entire corporation.

Our paper is also related to Spearot (2013), which examines the incentives for domestic and cross border mergers. It shows that if trade costs are high, implying that market access is the important factor, the high-productive firms do cross border mergers, mid-productive firms do domestic mergers and low-productive firms exit. However, if trade costs are small, i.e., market access incentives are low, only mid-productive firms acquire. Thus, Spearot (2013) shows how the interactions between foreign market access and cost reduction affect the incentives for mergers. In contrast, the benefits from market power and cost reduction are important for our paper. In our analysis, a relatively lower productive firm may have the higher incentive for a cross border merger even if there is no trade cost.

The seminal paper by Salant et al. (1983) initiated a vast literature in industrial organisation examining the reasons and implications of mergers in oligopoly. For example, they showed the implications of quantity competition (Salant et al., 1983), price competition (Deneckere and Davidson, 1985), synergic benefit and cost efficiency (Perry and Porter, 1985, Farrell and Shapiro, 1990), Stackelberg competition (Daughety, 1990, Kabiraj and Mukherjee, 2001, Huck et al., 2001), product differentiation (Lommerud and Sørgard, 1997), cost asymmetry (Kabiraj and Mukherjee, 2000), entry of firms (Werden and Froeb, 1998, Spector, 2003, Davidson and Mukherjee, 2007), vertical pricing (Lommerud et al., 2005, Cao et al., 2019), multidivisional firms (Creane and Davidson, 2004), multidimensional competition (Davidson and Ferrett, 2007) and strategic tax policy (Liu et al., 2015). Unlike these papers, we show how productivity improvement affects the incentive for a merger.

3. The basic model

Consider an economy with two countries: home (H) and foreign (F). Assume that there is a firm in each country: Firm F in the foreign country and Firm H in the home country. To prove our point in the simplest way, we consider an international Cournot duopoly in this section. We assume that the firms produce differentiated products and compete in the home-country market. We will show in Section 4 that our results will go through even if we consider Cournot oligopoly or two-way trade or Bertrand competition.

Firm F can serve country H in the following ways:

Export (X): Firm F can serve country H through export by incurring a positive per-unit transportation cost t.

Greenfield FDI (G): Firm F can set up a plant in country H by incurring a setup cost, G, and serves country H from that plant.

Cross Border Merger (M): Firms F and H can merge. The merged firm produces with the best available technology and merger requires a fixed cost, K. This cost may occur due to organizational, managerial or technological factors (see, e.g., Hart and Tirole, 1990).

Although Firm F has another option, i.e., not serving country H, we will assume that the parameter values are such that this option does not occur in equilibrium. We will do this because considering the option will not add new insights to our main purpose. Hence, our model is the one-way trade and investment version of Horstman and Markusen (1992) with a cross border merger.

As in NY, we consider that labour is the only factor of production, and the wage rates in both countries are the same and equal to *w*. The same wage rate in our paper eliminates the reason for FDI found in Nocke and Yeaple (2008). Firms differ in terms of their labour productivities, and the technologies of Firms F and H are given by $q_F = \frac{L_F}{\lambda}$ and $q_H = L_H$ respectively, where q_F and q_H are the outputs of Firms F and H respectively, and the labor productivity in Firm H is *1* but it is in Firm F is $\frac{1}{\lambda}$ with $\lambda \in [0,1]$. Hence, Firm F is more productive than Firm H.[8] We assume that Firm F can use the same technology under export, greenfield FDI and merger. This assumption makes our results comparable to the results of NY, where the firms are heterogeneous in terms of internationally mobile capabilities.

Following Bowley (1924), we assume that the representative consumer in country H has the following utility function:[9]

$$U = (q_F + q_H) - \left(\frac{q_F^2}{2} + \frac{q_H^2}{2}\right) - \gamma q_F q_H + m$$

where *m* stands for the numeraire commodity, and the parameter $\gamma \in [0,1]$ is the degree of product differentiation. The products are perfect substitutes if $\gamma = 1$, and they are isolated for $\gamma = 0$. The resulting inverse demand functions for goods q_F and q_H are:

$$p_F = 1 - q_F - \gamma q_H$$

[8] Hence, we obtain labour demand for Firm F and H: $L_F = \lambda q_F$ and $L_H = q_H$

[9] The Bowley type of market demand function is commonly used in the industrial organization literature.

$$p_H = 1 - q_H - \gamma q_F$$

where p_F and p_H are the prices.

A1: We will assume in this section that $w < \frac{2-\gamma}{2}$ and $t < \frac{(2-\gamma)(1-\mathrm{w})}{2}$.

Assumption **A1** will ensure that the equilibrium outputs of the firms are positive for any $\lambda \in [0,1]$ and $\gamma \in [0,1]$. Assumption **A1** is for simplicity and it helps to avoid corner solutions where one firm's equilibrium output is zero. Since a corner solution will not add new insights to our main purpose, we make this simplifying assumption.

We consider the following two-stage game in this section. At stage 1, Firm F determines whether to export or to undertake greenfield FDI or to merge with Firm H. At stage 2, the firms compete like Cournot duopolists in country H if Firm F either exports or undertakes greenfield FDI and the profits are realized. In case of merger, the merged firm behaves like a monopolist with two differentiated products and the profits are realized. We solve the game through backward induction.

If Firm F chooses to export, it determines its output by maximizing the following expression:

$$\max_{q_F}(1 - q_F - \gamma q_H - \lambda w - t)q_F, \quad (1)$$

and Firm H determines its output to maximize the following expression:

$$\max_{q_H}(1 - q_H - \gamma q_F - w)q_H. \quad (2)$$

Maximizing (1) and (2), we get the equilibrium outputs of Firms F and H respectively as:

$$q_F^X = \frac{(2-\gamma-w(2\lambda-\gamma)-2t)}{(4-\gamma^2)},\ q_H^X = \frac{(2-\gamma-w(2-\lambda\gamma)+\gamma t)}{(4-\gamma^2)}.$$

We assume that q_F^X and q_H^X are positive, i.e., $w < \frac{2-\gamma-2t}{2\lambda-\gamma}$ and $w < \frac{2-\gamma(1-t)}{2-\gamma\lambda}$, which hold under **A1**.

Let $\pi_F^X(\pi_H^X)$ represents Firm F's (Firm H's) equilibrium profit if Firm F chooses to export. The equilibrium profits of Firms F and H are:

$$\pi_F^X = \frac{(2-\gamma-w(2\lambda-\gamma)-2t)^2}{(4-\gamma^2)^2} \tag{3}$$

$$\pi_H^X = \frac{(2-\gamma-w(2-\lambda\gamma)+\gamma t)^2}{(4-\gamma^2)^2}. \tag{4}$$

If Firm F undertakes greenfield FDI, it maximizes the following profit function:

$$\max_{q_F}(1- \ q_F - \gamma q_H - \lambda w)q_F - G \tag{5}$$

while Firm H maximizes the following profit function:

$$\max_{q_H}(1- \ q_H - \gamma q_F - w)q_H. \tag{6}$$

Maximizing (5) and (6), we obtain the equilibrium outputs of Firms F and H respectively as:

$$q_F^G = \frac{(2-\gamma-w(2\lambda-\gamma))}{(4-\gamma^2)}, q_H^G = \frac{(2-\gamma-w(2-\lambda\gamma))}{(4-\gamma^2)}.$$

We assume that q_F^G, q_H^G are positive, i.e., $w < \frac{(2-\gamma)}{(2-\lambda\gamma)}$, which holds under **A1**.

Let $\pi_F^G(\pi_H^G)$ represents Firm F's (Firm H's) equilibrium profit if Firm F undertakes greenfield FDI. The equilibrium profits of Firms F and H are:

$$\pi_F^G = \frac{(2-\gamma-w(2\lambda-\gamma))^2}{(4-\gamma^2)^2} - G \tag{7}$$

$$\pi_H^G = \frac{(2-\gamma-w(2-\lambda\gamma))^2}{(4-\gamma^2)^2}. \tag{8}$$

Firm F prefers greenfield FDI compared to export if $\pi_F^G > \pi_F^X$ or:

$$G < -\frac{4t(-2+t+2\lambda w+\gamma-w\gamma)}{(-4+\gamma^2)^2} \equiv G_1 \tag{9}$$

where $G_1 > 0$.

3.1. Greenfield FDI vs. cross border merger

Consider $G < G_1$, i.e., Firm F prefers greenfield FDI compared to export. We know from equations (7) and (8) that if Firm F undertakes greenfield FDI, the profits of firms F and H are $\pi_F^G = \frac{(2-\gamma-w(2\lambda-\gamma))^2}{(4-\gamma^2)^2} - G$, and $\pi_H^G = \frac{(2-\gamma-w(2-\lambda\gamma))^2}{(4-\gamma^2)^2}$ respectively.

If firms F and H merge, the merged firm maximizes the following profit function:

$$\max_{q_F,q_H}(1- q_F - \gamma q_H - \lambda w)q_F + (1- q_H - \gamma q_F - \lambda w)q_H - K. \quad (10)$$

The merged firm produces differentiated products in county H. Merger allows Firm F to avoid the cost of greenfield FDI, but the merged firm incurs a cost of merger, K. Since Firm F is more efficient than Firm H, the merged firm uses the technology of Firm F and $\frac{1}{\lambda}$ is the productivity of the merged firm. It may worth mentioning that the products are horizontally differentiated due to the factors, such as packaging, design and after sales service, but both products can be produced with the same process technology, implying that there is an internationally mobile factor.

If Firms F and H merge, the equilibrium outputs and the profit of the merged firm are respectively:

$$q_F^M = q_H^M = \frac{(1-\lambda w)}{2(1+\gamma)}$$

$$\pi_{F+H}^M = \frac{(1-\lambda w)^2}{2(1+\gamma)} - K. \quad (11)$$

The output of the merged firm is positive, i.e., $w < \frac{1}{\lambda}$, under **A1**.

If greenfield FDI is the alternative to merger, a merger between firms F and H is profitable if:

$$\pi_{F+H}^M > \pi_F^G + \pi_H^G.$$

Hence, the cross border merger occurs if:

$$K < \frac{(1-\lambda w)^2}{2(1+\gamma)} - \left(\frac{(2-\gamma-w(2\lambda-\gamma))^2}{(4-\gamma^2)^2} + \frac{(2-\gamma-w(2-\lambda\gamma))^2}{(4-\gamma^2)^2} - G\right) \equiv K_1. \tag{12}$$

The value of K_1 shows the maximum gain from merger compared to greenfield FDI. A higher value for K_1 suggests that the gain from merger increases and therefore, increases the possibility of the cross border merger. It may worth pointing out that greenfield FDI can be preferable than the cross border merger only if $G < K$. If $K < G$, cross border merger will always occur.

Proposition 1: *Assume that greenfield FDI is the alternative to cross border merger.*

(i) If $\gamma=0$, the incentive for a merger increases with a higher productivity of Firm F.

(ii) Consider $\gamma \in (0,1]$. The incentive for a merger decreases with a higher productivity of Firm F if competition is intense (i.e., $\gamma > \gamma^*$) and the marginal cost of Firm F is significantly lower than that of Firm H (which happens for $\lambda < \lambda^*$ and $w > w^*$), where $\lambda^* = \frac{1+\frac{8(1-w)\gamma(1+\gamma)}{8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma))}}{w}$, $w^* = \frac{(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)}$ and $\gamma^* = (\sqrt{3}-1)$. *However, if either competition is not intense (i.e., $\gamma < \gamma^*$) or the marginal cost of Firm F is not significantly lower than that of Firm H (i.e., either $\lambda > \lambda^*$ or $w < w^*$), the incentive for a merger increases with a higher productivity of Firm F.*

Proof: See **Appendix A**. ■

Although the implications of $\gamma=0$ follows from Proposition 1(ii), we show this case explicitly in Proposition 1(i), since this case is similar to NY, as there is no competition among the firms when $\gamma=0$. In this situation, we obtain the result like NY, i.e., higher productive firms do mergers. Like NY, the efficiency argument is the reason for this result.

Proposition 1(ii) contrasts with NY, and shows that in an industry with competing firms, we may observe that a less productive firm is involved in merger while a high productive firm is involved in greenfield FDI.

Figures 1(a, b) provide diagrammatic representations of Proposition 1. A higher productivity of Firm F (i.e., lower λ) increases the profit of the merged firm, i.e., π^{M}_{F+H}, by reducing its cost of production. It also incraeses the total profits of Firms F and H under greenfield FDI, i.e., $(\pi^{G}_{F} + \pi^{G}_{H})$, since a higher productivity of Firm F creates production efficiency under greenfield FDI by shifting output from Firm H to a more cost efficient Firm F. Hence, a higher productivity of Firm F increases (decreases) the incentive for a merger if it increases the profit of the merged firm more (less) than the total profits of Firms F and H under greenfield FDI. Figures 1(a, b) show these situations. The curve *AA* shows "how the profit increase under merger following a lower λ varies with λ", and the curve *BB* shows "how λ affects the rise in total profits of Firms F and H under greenfield FDI following a lower λ". The technical details of the curves *AA* and *BB* are in **Appendix B**.

Figure 1(a) plots the case for $w > w^{*}$ and $\gamma > \gamma^{*}$, and shows that a higher productivity of Firm F (i.e., a lower λ) decreases (increases) the incentive for a merger for $\lambda < (>) \lambda^{*}$.

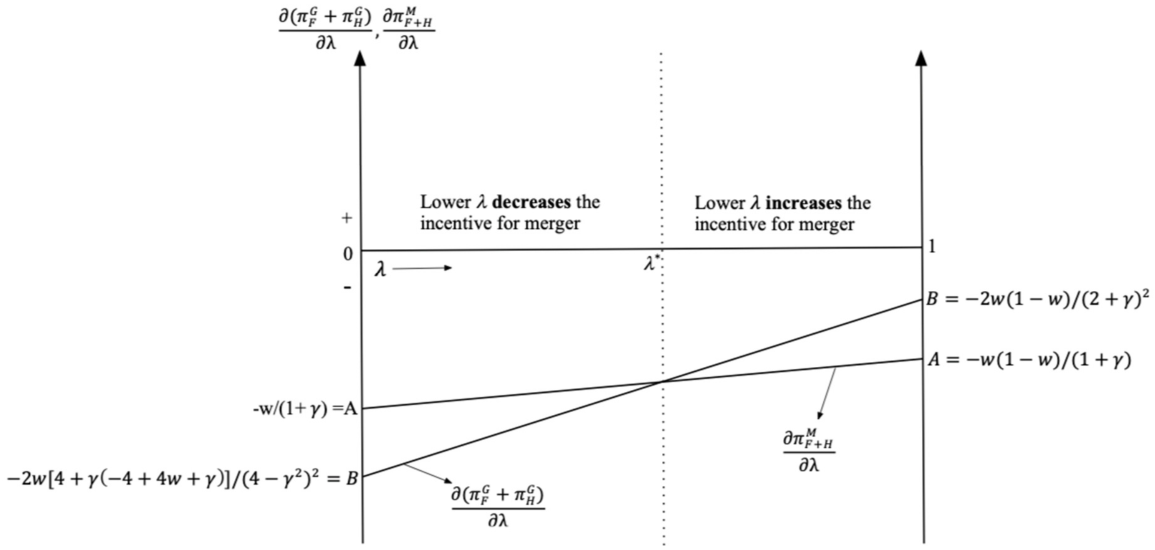

Figure 1(a): When $w > w^*$ and $\gamma > \gamma^*$.

Figure 1(b) plots the case for $w < w^*$ or $\gamma < \gamma^*$ and shows that a higher productivity of Firm F increases the incentive for a merger for $\lambda \in [0,1]$.

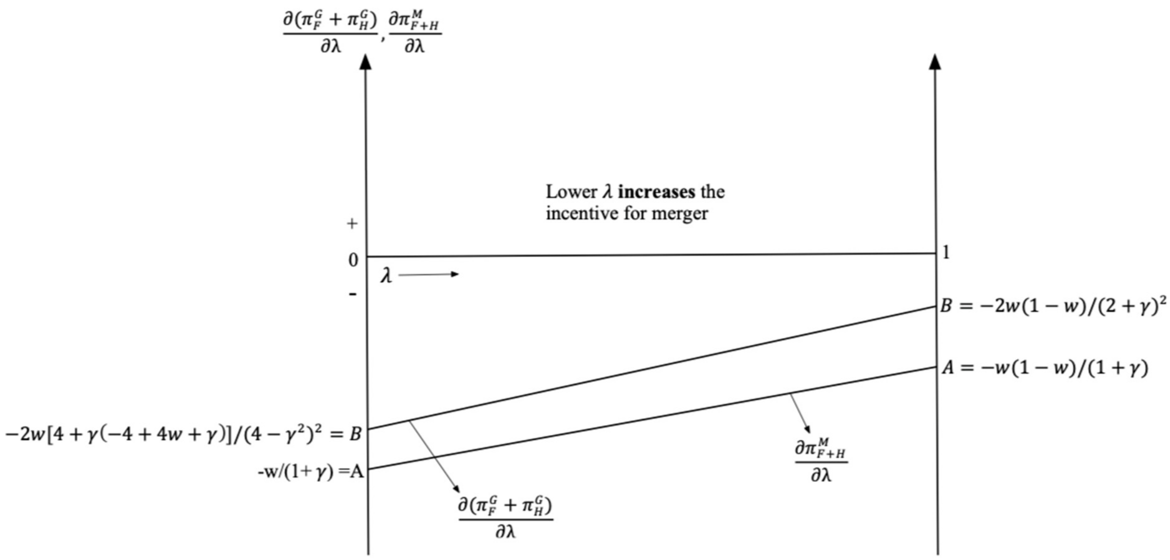

Figure 1(b): When $w < w^*$ or $\gamma < \gamma^*$.

To understand the intuition for Proposition 1, we can decompose the total gain from a merger into competition and technology transfer effects, i.e.,

$$\underbrace{\pi^M_{F+H}(\frac{1}{\lambda},\frac{1}{\lambda})-(\pi^G_F(\frac{1}{\lambda})+\pi^G_H(1))}_{Total\ Effect}=\underbrace{[\pi^M_{F+H}(\frac{1}{\lambda},1)-(\pi^G_F(\frac{1}{\lambda})+\pi^G_H(1))]}_{Competition\ Effect}+\underbrace{[\pi^M_{F+H}(\frac{1}{\lambda},\frac{1}{\lambda})-\pi^M_{F+H}(\frac{1}{\lambda},1)]}_{Technology\ Transfer\ Effect},$$

where the first and second arguments in $\pi^M_{F+H}(.,.)$ show the productivities at which the merged firm produce the products of Firms F and H respectively, and the arguments in $\pi^G_F(\frac{1}{\lambda})$ and $\pi^G_H(1)$ show the productivities at which Firms F and H produce their products under greenfield FDI respectively.

The competition effect shows how a merger benefits the firms by reducing competition only. Hence, assume that the technologies of Firms F and H are used to produce the respective products under greenfield FDI and merger. The competition effect then shows the gain in profits under merger compared to greenfield FDI when the technologies of Firms F and H are used to produce the respective products under greenfield FDI and merger, i.e., $\pi^M_{F+H}(\frac{1}{\lambda},1)-(\pi^G_F(\frac{1}{\lambda})+\pi^G_H(1))$.

The technology transfer effect shows the merged firm's gain in profits from using Firm F's technology for both products compared to the situation where the merged firm uses the technologies of Firms F and H for the respective products, i.e., $\pi^M_{F+H}(\frac{1}{\lambda},\frac{1}{\lambda})-\pi^M_{F+H}(\frac{1}{\lambda},1)$.

A higher productivity of Firm F increases (decreases) the incentive for a merger if its total impact on the competition and technology transfer effects is positive (negative). The technical details of these effects are shown in **Appendix C**. We provide an intuitive discussion here.

If the productivity of Firm F increases, it creates a positive impact on the technology transfer effect by increasing the merged firm's benefit from using Firm F's technology to produce the product of Firm H, as long as the products are differentiated. Hence, a higher productivity of Firm F decreases the incentive for a merger through its total impact on the technology transfer and competition effects if it creates a negative impact on the competition effect, which dominates its positive impact on the technology transfer effect. We find that this happens if the products are close substitutes (i.e., $\gamma > \gamma^*$), thus creating significant competition, and the marginal cost of Firm F is sufficiently lower than that of Firm H (which occurs for $w > w^*$ and $\lambda < \lambda^*$). To understand the implications of these factors in the simplest way, we will consider two extreme cases of homogeneous products ($\gamma = 1$) and isolated products ($\gamma = 0$). Since the profits are continuous in γ, our arguments will hold respectively for close substitutes (i.e., $\gamma > \gamma^*$) and much differentiated products (i.e., $\gamma < \gamma^*$).

First, consider the case of homogeneous products. In this situation, the merged firm will produce the product of Firm F only, implying that there is no technology transfer effect. Hence, the effect of a higher productivity of Firm F on the incentive for a merger will be determined by its impact on the competition effect. Since a higher productivity of Firm F increases the profits of the merged firm as well as the total profits of Firms F and H under greenfield FDI, it creates a positive (negative) impact on the competition effect if the profit of the merged firm increases more (less) than the total profits of Firms F and H under greenfield FDI.[10]

[10] Although a higher productivity of Firm F increases the total profits of Firms F and H under greenfield FDI, it increases the profit of Firm F but reduces the profit of Firm H. Hence, a higher productivity of Firm F can reduce the incentive for a merger only if it increases the profit of Firm F under greenfield FDI more than the profit of the merged firm.

A higher productivity of Firm F affects the total profits under merger and under greenfield FDI in two ways. On one hand, it tends to increase the total profits under merger more compared to that of under greenfield FDI due to the higher market concentration under the former than the latter. This is similar to the Schumpeterian view where the benefit from a cost reduction is more in a concentrated market. On the other hand, a higher productivity of Firm F helps to increase the total profits under greenfield FDI by increasing production efficiency, since it shifts outputs from the high-cost Firm H to the low-cost Firm F. This effect is absent under merger.

If the wage is higher than a critical value (i.e., $w > w^*$) and Firm F is sufficiently technologically superior than Firm H (i.e., $\lambda < \lambda^*$), the marginal cost of Firm F, which is λw, is sufficiently lower than that of Firm H, which is w. The significant marginal cost difference between the firms makes Firm F a near monopoly under greenfield FDI, and a higher productivity of Firm F increases production efficiency under greenfield FDI significantly. In this situation, the effect of a higher production efficiency under greenfield FDI dominates the effect of a higher market concentration under merger, and a higher productivity of Firm F reduces the incentive for a merger.

However, if either λ is high or λ is low but $w < w^*$, the marginal costs of the firms are very similar, and, unlike the above-mentioned case, a higher productivity of Firm F does not increase production efficiency under greenfield FDI significantly. In this situation, the benefit from a higher market concentration under merger helps to increase the incentive for a merger following an increased productivity of Firm F.

The above discussion considered homogeneous products to eliminate the technology transfer effect completely. However, the above arguments hold even if the products are differentiated but close substitutes (i.e., $\gamma > \gamma^*$). In this situation, a higher productivity of Firm F creates a small impact on the technology transfer effect, since the merged firm's gain from producing Firm H's product is small when the products are close substitutes.

Now consider the other extreme case of isolated products. In this situation, there is no benefit due to the competition effect since Firms F and H are monopolists under greenfield FDI for the respective products. However, a higher productivity of Firm F creates a positive impact on the technology transfer effect by reducing the cost for Firm H's product. Hence, a higher productivity of Firm F increases the incentive for a merger in this situation. Similar argument holds even if the products are not isolated but much differentiated (i.e., $\gamma < \gamma^*$). In this situation, a higher productivity of Firm F creates a small impact on the competition effect, since the near monopolies of Firms F and H under greenfield FDI for the respective products create negligible benefits due to the competition effect.

3.2. Export vs. cross border merger

We know from equation (9) that Firm F prefers export over greenfield FDI if $G > G_1$. Now we will see Firm F's preference for cross border merger when export is the alternative to merger.

We know from (3) and (4) that if Firm F exports, the profits of Firms F and H are $\pi_F^X = \frac{(2-\gamma-w(2\lambda-\gamma)-2t)^2}{(4-\gamma^2)^2}$, and $\pi_H^X = \frac{(2-\gamma-w(2-\lambda\gamma)+\gamma t)^2}{(4-\gamma^2)^2}$ respectively. If Firms F and H merge, we know from (11) that the profit of the merged firm is $\pi_{F+H}^M = \frac{(1-\lambda w)^2}{2(1+\gamma)} - K$.

Merger between firms F and H occurs if the profit of the merged firm, Firm π_{F+H}^M, exceeds the total profits of Firms F and H under export by Firm F, i.e. if:

$$\pi_{F+H}^M > \pi_F^X + \pi_H^X.$$

It follows from (3), (4) and (11), that cross border merger occurs if:

$$K < \frac{(1-\lambda w)^2}{2(1+\gamma)} - \left(\frac{(2-\gamma-w(2\lambda-\gamma)-2t)^2}{(4-\gamma^2)^2} + \frac{(2-\gamma-w(2-\lambda\gamma)+\gamma t)^2}{(4-\gamma^2)^2}\right) \equiv K_2. \tag{13}$$

The above condition shows the maximum gain from merger compared to export, thus a higher value of K_2 suggests that the firms have a higher incentive for a cross border merger.

The following proposition shows results which are qualitatively similar to Proposition 1 but it also adds a restriction on the transportation cost *t*.

Proposition 2: *Assume that export is the alternative to cross border merger.*

(i) If $\gamma=0$*, the incentive for a merger increases with a higher productivity of Firm F.*

(ii) Consider $\gamma \in (0,1]$. *The incentive for a merger decreases with a higher productivity of Firm F if competition is intense (i.e.,* $\gamma > \gamma^{**}$*) and the marginal cost of Firm F is significantly lower than that of Firm H (which happens for* $\lambda < \lambda^{**}$ *,* $w > w^{**}$ *and* $t < t^*$ *), where* $\lambda^{**} = \frac{-8w\gamma(1+\gamma)+2t(1+\gamma)(4+\gamma^2)+(2-\gamma)^2(2+2\gamma+\gamma^2)}{w(8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma)))}$, $w^{**} = \frac{2t(1+\gamma)(4+\gamma^2)+(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)}$, $t^* = \frac{(2-\gamma)(2+\gamma)(-2+\gamma(2+\gamma))}{2(1+\gamma)(4+\gamma^2)}$ and $\gamma^{**} = (\sqrt{3}-1)$. *However, if either competition is not intense (i.e.,* $\gamma < \gamma^{**}$*) or the marginal cost of Firm F is not significantly lower than that of Firm H (i.e., either* $\lambda > \lambda^{**}$ *or* $w < w^{**}$ *or* $t > t^*$*), the incentive for a merger increases with a higher productivity of Firm F.*

Proof: See **Appendix D**. ■

Like Proposition 1(i), Proposition 2(i) considers a case similar to NY where the firms do not compete in the product market. We get a result similar to NY in this situation.

Proposition 2(ii) contrasts with NY, and the reason for Proposition 2(ii) is similar to that of Proposition 1(ii). Along with the factors mentioned in Proposition 1(ii), the transportation cost also plays an important role in Proposition 2(ii), since it affects the effective marginal cost of Firm

F. Since a lower transportation cost helps to reduce the effective marginal cost of Firm F, it is required for the negative relationship between Firm F's productivity and the incentive for a cross border merger.

Like the previous subsection, we can decompose the impacts of λ into its impacts on the competition and technology transfer effects. Similarly, we can draw figures like Figures 1(a, b).[11] However, we skip these aspects here to avoid repetition.

4. Discussion

Considering a Cournot duopoly where firms compete in the domestic market only, we have shown that there can be a non-monotonic relationship between the foreign firm's productivity and the incentive for a cross border merger. We will show in this section that our qualitative results hold even if there are more than two firms in the market and a merger does not create a monopoly or the firms compete in both countries or the product market is characterised by Bertrand competition. The effects created by lower competition and technology transfer under merger, which we discussed in the previous section, are also responsible for the results in this section.

4.1. The implications of Cournot oligopoly

The purpose of this subsection is to show that our qualitative results of the previous section do not depend on the duopoly assumption. To show this, we assume that, in addition to Firms F and H, there is another firm, Firm 3. Like Section 3, we consider that the firms compete in the domestic

[11] If t is sufficiently high, we can get the extreme points of the *BB* curve (i.e., *BB* at $\lambda = 0$ and at $\lambda = 1$) to be positive depending on w and γ.

country only. To show the implications of oligopoly under Cournot competition in the simplest way, we assume that the products are perfect substitutes, i.e., $\gamma = 1$.

The sequence of the moves is like Section 3. At stage 1, Firm F determines whether to export or to undertake greenfield FDI or to merge with Firm H. At stage 2, the firms compete like Cournot oligopolists in country H conditional on Firm F's decision in stage 1 and the profits are realized. We solve the game through backward induction.

4.1.1. Firm 3 is a domestic firm

We assume in this subsection that Firm 3 is a domestic firm which is based in country H, and Firm H and Firm 3 have the same production technologies. In case of a merger, Firms F and H merge and Firm 3 becomes the non-merged firm. In this subsection, we assume $w < \frac{1}{2}$ and $t < \frac{1-w}{3}$ to ensure positive outputs always. We show in **Appendix E** that the qualitaive results derived in Section 3 hold in this situation.

4.1.2. Firm 3 is a foreign firm in country F

We have considered in the previous subsection a Cournot oligopoly with two symmetric domestic firms. We will consider an opposite situation in this subsection. We will consider two foreign firms, Firm F and Firm 3, with symmetric technologies, and in case of a merger, Firms F and H merge and Firm 3 becomes the non-merged firm. We assume that Firm 3 exports always.[12] This assumption helps to show our results in the simplest way by eliminating strategic FDI decisions by Firms F and 3. In this subsection, we assume $w < \frac{1}{3}$ and $t < \frac{1-w}{3}$ to ensure positive outputs

[12] This may happen if Firm 3 faces significantly higher cost of FDI.

always. We show in **Appendix F** that the qualitaive results derived in Section 3 hold in this situation.

4.2. Competition in both countries

We will show in this subsection that our results of Section 3 hold even if the firms compete in both countries.

Assume that both Firms F and H have their production plants already in their home countries. Both firms can sell the products to both countries. To show our results in the simplest way, we will consider a Cournot duopoly with $\gamma = 1$, symmetric demand functions in both countries, segmented markets, both firms facing the same per-unit transportation costs, and the fixed costs of greenfield FDIs are so high that greenfield FDI is not a feasible option for either firm and Firm F (H) firm sells to country H (F) only through export. Hence, this setup is similar to the reciprocal dumping model of Brander and Krugman (1983) and the one-plant strategy of Horstman and Markusen (1992) where the respective firm sells to both countries from their home plants.

Under merger, the merged firm uses the efficient technology of Firm F and uses the plant of Firm F (H) to serve the market in country H (F). We assume in this subsection that $w < \frac{1}{2}$ and $t < \frac{1-2w}{2}$, to ensure positive outputs. We show in **Appendix G** that the qualitaive results derived in Section 3 hold in this situation.

4.3. Bertrand competition

Now we show the implications of Bertrand competition. Like Section 3, we consider a duopoly and for $\gamma \in [0,1)$ to avoid the well-known "Bertrand paradox". To ensure positive outputs of the firms, we assume in this subsection that $w < (1-\frac{\gamma}{2-\gamma^2})$ and $t < \frac{(2-\gamma-\gamma^2)(1-w)}{(2-\gamma^2)}$.

We consider a game like Section 3 with the exception that the product market is characterised by Bertrand competition. We show in **Appendix H** that the qualitative results of Section 3 hold in this situation.

5. Conclusion

We show in this paper how the productivity of a foreign firm affects the incentive for a cross border merger. We show that the predictions of Nocke and Yeaple (2007), suggesting that the most productive firms prefer a cross border merger, may not hold true if the competition reducing effect of a merger is considered. We observed a non-monotonic relationship between productivity and the incentive for a merger and showed that these results hold under both Cournot and Bertrand competition, and under different market structures. Our findings provide an explanation for the existing mixed empirical results and suggest that more empirical analyses are needed on this issue.

Appendix

A: Proof of Proposition 1

(i) If $\gamma=0$, we get $\frac{\partial K_1}{\partial \lambda} = -\frac{1}{2} w(1-\lambda w) < 0$.

(ii) If $\gamma \in [0,1]$, we get $\frac{\partial K_1}{\partial \lambda} = \frac{w[w\left(8+\gamma\left(-8+\gamma(-10+(-2+\gamma)\gamma)\right)\right)\lambda-\left((2-\gamma)^2\left(2+\gamma(2+\gamma)\right)-8w\gamma(1+\gamma)\right)]}{(1+\gamma)(4-\gamma^2)^2}$. Hence, $\frac{\partial k_1}{\partial \lambda} > (<) 0$ for $(wJ\lambda - S) > (<) 0$, where $J = (8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma)))$ and $S = \left((2-\gamma)^2\left(2+\gamma(2+\gamma)\right) - 8w\gamma(1+\gamma)\right)$.

We find $wJ\lambda \le wJ = w\left[8+\gamma\left(-8+\gamma(-10+(-2+\gamma)\gamma)\right)\right] < S = [(2-\gamma)^2\left(2+\gamma(2+\gamma)\right) - 8w\gamma(1+\gamma)]$. Hence, $\frac{\partial k_1}{\partial \lambda} > 0$ is possible provided $S < 0$.

We find $S = ((2-\gamma)^2\left(2+\gamma(2+\gamma)\right) - 8w\gamma(1+\gamma)) < 0$ if $w > w^* = \frac{(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)}$. Since we are considering $w < \frac{2-\gamma}{2}$, $w > w^*$ is possible if $\frac{(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)} < \frac{2-\gamma}{2}$, which happens for $\gamma > \gamma^* = (\sqrt{3}-1)$. Hence, $S = ((2-\gamma)^2\left(2+\gamma(2+\gamma)\right) - 8w\gamma(1+\gamma)) > (<) 0$ for $w < w^*$ or $\gamma < \gamma^*$ ($w > w^*$ and $\gamma > \gamma^*$).

If $S < 0$,[13] i.e., $w > w^*$ and $\gamma > \gamma^*$, $\frac{\partial k_1}{\partial \lambda} > 0$ for $\lambda < \frac{S}{wJ} = \frac{1+\frac{8(1-w)\gamma(1+\gamma)}{8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma))}}{w} = \lambda^*$, where $\lambda^* < 1$.

Therefore, $\frac{\partial K_1}{\partial \lambda} > 0$ for $\lambda < \lambda^*$, $w > w^*$ and $\gamma > \gamma^*$. However, $\frac{\partial K_1}{\partial \lambda} < 0$ for $\lambda > \lambda^*$ or $w < w^*$ or $\gamma < \gamma^*$. ■

[13] Since $S > wJ$, we get $wJ < 0$ when $S < 0$.

B Figures 1(a) and 1(b): Figure 1(a, b) provides a diagrammatic representation of Proposition 1. We get $\frac{\partial(\pi^M_{F+H})}{\partial\lambda} - \frac{\partial(\pi^G_F + \pi^G_H)}{\partial\lambda} > (<) 0$ if $M > (<) GF$ or $(-GF) > (<)(-M)$, where $M \equiv \frac{\partial(\pi^M_{F+H})}{\partial\lambda}$ and $GF \equiv \frac{\partial(\pi^G_F + \pi^G_H)}{\partial\lambda}$.

The curve *AA* shows $\frac{\partial\pi^M_{F+H}}{\partial\lambda} \equiv M = \frac{-w(1-\lambda w)}{1+\gamma}$, i.e., how the profit of the merged firm changes as λ falls. We get that $\frac{\partial M}{\partial\lambda} = \frac{w^2}{1+\gamma}$, $M(\lambda = 0) = \frac{-w}{1+\gamma}$ and $M(\lambda = 1) = \frac{-w(1-w)}{1+\gamma}$. The curve *BB* shows $\frac{\partial(\pi^G_F + \pi^G_H)}{\partial\lambda} \equiv GF = \frac{2w[-4-\gamma(-4+4w+\gamma)+w(4+\gamma^2)\lambda]}{(4-\gamma^2)^2}$, i.e., how the total profits of Firms F and H under greenfield FDI change as λ falls. We get $\frac{\partial GF}{\partial\lambda} = \frac{2w^2(4+\gamma^2)}{(4-\gamma^2)^2}$, $GF(\lambda = 0) = \frac{-2w[4+\gamma(-4+4w+\gamma)]}{(4-\gamma^2)^2}$ and $GF(\lambda = 1) = \frac{-2w(1-w)}{(2+\gamma)^2}$. We also get $GF(\lambda = 1) > M(\lambda = 1)$. However, $GF(\lambda = 0) < (>) M(\lambda = 0)$ if $w > (<) w^* \equiv \frac{(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)}$ where $w^* < (>) \frac{2-\gamma}{2}$ for $\gamma > (<) \gamma^* = (\sqrt{3} - 1)$.

Figure 1(a) plots the case for $w > w^*$ and $\gamma > \gamma^*$. It shows that when $w > w^*$ and $\gamma > \gamma^*$, there exists $\lambda < \lambda^*$ for which $GF < M$ or $(-M) < (-GF)$, suggesting that if λ reduces, the profit increase under merger is less than the total profit increase of Firms F and H under greenfield FDI for $\lambda < \lambda^*$, $w > w^*$ and $\gamma > \gamma^*$. Hence, a higher productivity of Firm F decreases the incentive for a merger if $\lambda < \lambda^*$, $w > w^*$ and $\gamma > \gamma^*$. Even if $w > w^*$ and $\gamma > \gamma^*$ but $\lambda > \lambda^*$, a higher productivity of the foreign firm increases the incentive for a merger.

C The impacts of Firm F's productivity on the competition and technology transfer effects: Under merger, assume that Firms F and H determine outputs to maximise their joint profits but use their own technologies to produce the respective products. Hence, the outputs maximise $[(1 - q_F - \gamma q_H - \lambda w)q_F + (1 - q_H - \gamma q_F - w)q_H]$. Straightforward calculations show that both products are produced if $\lambda > \frac{-1+w+\gamma}{w\gamma}$, which can happen for $\gamma < 1$. The corresponding total gross profit of Firms F and H is $\frac{(1-(1-w)\gamma-\lambda w)(1-\lambda w)+(1-\gamma-w(1-\gamma\lambda))(1-w)}{4(1-\gamma^2)}$. However, if $\lambda < \frac{-1+w+\gamma}{w\gamma}$, which can happen for $\gamma > (1-w)$, the joint profit maximising output is $\frac{1-\lambda w}{2}$, which is the output of Firm F's product only. The corresponding total gross profit of Firms F and H is $\frac{(1-\lambda w)^2}{4}$.

We call $[\frac{(1-(1-w)\gamma-\lambda w)(1-\lambda w)+(1-\gamma-w(1-\gamma\lambda))(1-w)}{4(1-\gamma^2)} - \frac{(2-\gamma-w(2\lambda-\gamma))^2+(2-\gamma-w(2-\lambda\gamma))^2}{(4-\gamma^2)^2}] \equiv \mathrm{C}_1$ and $[\frac{(1-\lambda w)^2}{4} - \frac{(2-\gamma-w(2\lambda-\gamma))^2+(2-\gamma-w(2-\lambda\gamma))^2}{(4-\gamma^2)^2}] \equiv \mathrm{C}_1'$ as the competition effects, where C_1 (C_1') is relevant for $\lambda > (<) \frac{-1+w+\gamma}{w\gamma}$. The first term in C_1 (C_1') is the total gross profit of Firms F and H under merger with their own technologies and the second term in C_1 (C_1') is their total gross profits under greenfield FDI. There is no competition effect if the products are isolated, i.e., $\gamma = 0$.

We then call $[\frac{(1-\lambda w)^2}{2(1+\gamma)} - \frac{(1-(1-w)\gamma-\lambda w)(1-\lambda w)+(1-\gamma-w(1-\gamma\lambda))(1-w)}{4(1-\gamma^2)}] \equiv \mathrm{C}_2$ and $[\frac{(1-\lambda w)^2}{2(1+\gamma)} - \frac{(1-\lambda w)^2}{4}] \equiv \mathrm{C}_2'$ as the technology transfer effect, where C_2 (C_2') is relevant for $\lambda > (<) \frac{-1+w+\gamma}{w\gamma}$. The first term in C_2 (C_2') is the total gross profit of Firms F and H under merger while using Firm F's technology to produce both products, and the second term in C_2 (C_2') is their total gross profit under merger while using the technologies of Firms F and H for the respective products. There is no technology transfer effect if the products are homogeneous, i.e., $\gamma = 1$.

Since $\frac{\partial C_2}{\partial \lambda} = -\frac{w(1-(1+w)\gamma-w(1-2\gamma)\lambda)}{2(1-\gamma^2)} < 0$ for $\lambda > \frac{-1+w+\gamma}{w\gamma}$ and $\frac{\partial C_2'}{\partial \lambda} = -\frac{w(1-\gamma)(1-\lambda w)}{2(1+\gamma)} < 0$ for $\lambda < \frac{-1+w+\gamma}{w\gamma}$, a higher productivity of Firm F (i.e., a lower λ) increases the incentive for a merger through its impact on the technology transfer effect. Hence, a higher productivity of Firm F may reduce the incentive for a merger only if it reduces C_1 or C_1', capturing the competition effect.

We get that $\frac{\partial C_1}{\partial \lambda} = -\frac{w\gamma^2(4-8(1-w)\gamma-(1-w)\gamma^3-4\lambda w+5\gamma^2(1-\lambda w))}{2(4-\gamma^2)^2(1-\gamma^2)} < 0$ for $\lambda > \frac{-1+w+\gamma}{w\gamma}$ but $\frac{\partial C_1'}{\partial \lambda} = \frac{w\gamma(-(2-\gamma)^2(4+\gamma)+w(16-\gamma(12-\gamma^2)\lambda))}{2(4-\gamma^2)^2} > (<) 0$ for $\lambda < (>) (\frac{1}{w} - \frac{16(1-w)}{w(12\gamma-\gamma^3)}) = \overline{\lambda}$, where $\overline{\lambda} < \frac{-1+w+\gamma}{w\gamma}$ and $\overline{\lambda} > 0$ for $w > \frac{(2-\gamma)^2(4+\gamma)}{16} = \overline{w}$. Hence, a higher productivity of Firm F reduces the incentive for a merger through its impact on the competition effect if *w* is higher than a critical value and λ is lower than a critical value.

Even if *w* is sufficiently high and λ is sufficiently low to make $\frac{\partial C_1'}{\partial \lambda} > 0$, a higher productivity of the foreign firm reduces the incentive for a merger provided the total effect of λ on C_1' and C_2' is positive, i.e., $(\frac{\partial C_1'}{\partial \lambda} + \frac{\partial C_2'}{\partial \lambda}) > 0$ or $\frac{\partial C_1'}{\partial \lambda} > -\frac{\partial C_2'}{\partial \lambda}$. This happens if the products are not very differentiated, i.e., γ is higher than a critical value, since low product differentiation makes the impact on the competition effect sufficiently stronger to outweigh the impact on the technology transfer effect.[14]

D: Proof of Proposition 2:

(i) If $\gamma = 0$, we get that $\frac{\partial K_2}{\partial \lambda} = -\frac{1}{2} w(1+t-\lambda w) < 0$.

(ii) If $\gamma \in [0,1]$, we get

$$\frac{\partial K_2}{\partial \lambda} = \frac{w[w(8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma)))\lambda-((2-\gamma)^2(2+\gamma(2+\gamma))+2t(1+\gamma)(4+\gamma^2)-8w\gamma(1+\gamma))]}{(1+\gamma)(4-\gamma^2)^2}.$$

Hence, $\frac{\partial K_2}{\partial \lambda} = \frac{\partial K_1}{\partial \lambda} - \frac{2t(1+\gamma)(4+\gamma^2)}{(1+\gamma)(4-\gamma^2)^2}$.

[14] We get
$\frac{\partial C_1'}{\partial \lambda} + \frac{\partial C_2'}{\partial \lambda} = \frac{w\gamma(-(2-\gamma)^2(4+\gamma)+w(16-\gamma(12-\gamma^2)\lambda))}{2(4-\gamma^2)^2} + (-\frac{w(1-\gamma)(1-\lambda w)}{2(1+\gamma)}) = \frac{w[8w\gamma(1+\gamma)-(2-\gamma)^2(2+\gamma(2+\gamma))+w(8+\gamma(-8+\gamma(-10-(2-\gamma)\gamma)))\lambda]}{(1+\gamma)(4-\gamma^2)^2} > 0$
when *w* and γ are sufficiently high and λ is sufficiently low.

Since the proof is like Proposition 1, we will be brief here.

We find $w[8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma))] < [(2-\gamma)^2(2+\gamma(2+\gamma))+2t(1+\gamma)(4+\gamma^2)-8w\gamma(1+\gamma)]$.

We also find $[(2-\gamma)^2(2+\gamma(2+\gamma))+2t(1+\gamma)(4+\gamma^2)-8w\gamma(1+\gamma)] < 0$ if $w > w^{**} = \frac{2t(1+\gamma)(4+\gamma^2)+(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)}$. Since we consider $w < \frac{2-\gamma}{2}$, $w > w^{**}$ is possible if $\frac{2t(1+\gamma)(4+\gamma^2)+(2-\gamma)^2(2+2\gamma+\gamma^2)}{8\gamma(1+\gamma)} < \frac{2-\gamma}{2}$, which happens if $t < t^* = \frac{(2-\gamma)(2+\gamma)(-2+\gamma(2+\gamma))}{2(1+\gamma)(4+\gamma^2)}$, and it is possible if $t^* > 0$, which happens for $\gamma > \gamma^{**} = (\sqrt{3}-1)$.

If $w > w^{**}$, $t < t^*$ and $\gamma > \gamma^{**}$, $\frac{\partial K_2}{\partial \lambda} > 0$ for $\lambda < \lambda^{**} = \frac{-8w\gamma(1+\gamma)+2t(1+\gamma)(4+\gamma^2)+(2-\gamma)^2(2+2\gamma+\gamma^2)}{w(8+\gamma(-8+\gamma(-10+(-2+\gamma)\gamma)))}$, where $\lambda^{**} < 1$.

Therefore, $\frac{\partial K_2}{\partial \lambda} > 0$ for $\lambda < \lambda^{**}$, $w > w^{**}$, $t < t^*$ and $\gamma > \gamma^{**}$. However, $\frac{\partial K_2}{\partial \lambda} < 0$ for $\lambda > \lambda^{**}$ or $w < w^{**}$ or $t > t^*$ or $\gamma < \gamma^{**}$. ■

E The implications of Cournot oligopoly: Firm 3 is a domestic firm: Straightforward calculations give that if Firm F exports, the equilibrium outputs are $q_F^X = \frac{1-w(3\lambda-2)-3t}{4}$ and $q_H^X = q_3^X = \frac{1-w(2-\lambda)+t}{4}$ and the corresponding profits are $\pi_F^X = \frac{(1-w(3\lambda-2)-3t)^2}{16}$ and $\pi_H^X = \pi_3^X = \frac{(1-w(2-\lambda)+t)^2}{16}$.

If Firm F undertakes greenfield FDI, the equilibrium outputs are $q_F^G = \frac{1-w(3\lambda-2)}{4}$, $q_H^G = q_3^G = \frac{1-w(2-\lambda)}{4}$ and the corresponding profits are $\pi_F^G = \frac{(1-w(3\lambda-2))^2}{16} - G$ and $\pi_H^G = \pi_3^G = \frac{(1-w(2-\lambda))^2}{16}$.

If Firms F and H merge, the merged firm competes with Firm 3 in country H as Cournot duopolists. Straightforward calculations give the equilibrium output and the profit of the merged firm as $q^M_{F+H} = \frac{1-2\lambda w+w}{3}$ and $\pi^M_{F+H} = \frac{(1-2\lambda w+w)^2}{9} - K$ respectively.

If greenfield FDI is the alternative to merger, a merger between Firms F and H is profitable if $\pi^M_{F+H} > \pi^G_F + \pi^G_H$, or

$$K < \frac{(1-2\lambda w+w)^2}{9} - \left(\frac{(1-w(3\lambda-2))^2}{16} + \frac{(1-w(2-\lambda))^2}{16} - G\right) \equiv K_3.$$[15]

We get $\frac{\partial K_3}{\partial \lambda} > (<) 0$ for $\lambda < (>) \hat{\lambda} = \frac{1}{13}\left(20 - \frac{7}{w}\right)$, where $\hat{\lambda} < 1$. $\frac{\partial K_3}{\partial \lambda} > 0$ is possible provided $\hat{\lambda} > 0$ which happens if $w > \hat{w} = \frac{7}{20}$. Therefore, $\frac{\partial K_3}{\partial \lambda} > 0$ for $\lambda < \hat{\lambda}$ and $w > \hat{w}$ but $\frac{\partial K_3}{\partial \lambda} < 0$ for $\lambda > \hat{\lambda}$ or $w < \hat{w}$.

Now consider Firm F's preference for a cross border merger when export is the alternative to merger. Merger between Firms F and H occurs if $\pi^M_{F+H} > \pi^X_F + \pi^X_H$, or

$$K < \frac{(1-2\lambda w+w)^2}{9} - \left(\frac{(1-w(3\lambda-2)-3t)^2}{16} + \frac{(1-w(2-\lambda)+t)^2}{16}\right) \equiv K_4.$$

We get $\frac{\partial K_4}{\partial \lambda} > (<) 0$ for $\lambda < (>) \tilde{\lambda} = \frac{-7-45t+20w}{13w}$, where $\tilde{\lambda} < 1$. $\frac{\partial K_4}{\partial \lambda} > 0$ is possible provided $\tilde{\lambda} > 0$ which happens if $w > \tilde{w} = \left(\frac{7}{20} + \frac{9t}{4}\right)$. Since we consider $w < \frac{1}{2}$, $w > \tilde{w}$ is possible if $\left(\frac{7}{20} + \frac{9t}{4}\right) < \frac{1}{2}$, which happens for $t < \tilde{t} = \frac{1}{15}$.[16] Therefore, $\frac{\partial K_4}{\partial \lambda} > 0$ for $\lambda < \tilde{\lambda}$, $w > \tilde{w}$ and $t < \tilde{t}$. However, $\frac{\partial K_4}{\partial \lambda} < 0$ for $\lambda > \tilde{\lambda}$ or $w < \tilde{w}$ or $t > \tilde{t}$.

[15] It is worth noting that even if $K = 0$, merger may not be profitable for any parametric configuration under Cournot oligopoly. This is different from the duopoly case considered in the previous section and the reason follows from the well-known paper by Salant et al. (1983).

[16] Note that $\tilde{t} = \frac{1}{15}$ is less than the minimum upper limit on t, which is $\frac{1}{6}$ and corresponds to $w = \frac{1}{2}$.

F The implications of Cournot oligopoly: Firm 3 is a foreign firm in country F: Straightforward calculations give that if Firm F exports, the equilibrium outputs are $q_F^X = q_3^X = \frac{1-w(2\lambda-1)-2t}{4}$ and $q_H^X = \frac{1-w(3-2\lambda)+2t}{4}$ and the corresponding profits are $\pi_F^X = \pi_3^X = \frac{(1-w(2\lambda-1)-2t)^2}{16}$ and $\pi_H^X = \frac{(1-w(3-2\lambda)+2t)^2}{16}$.

If Firm F undertakes greenfield FDI, the equilibrium outputs are $q_F^G = \frac{1-w(2\lambda-1)+t}{4}$, $q_H^G = \frac{1-w(3-2\lambda)+t}{4}$ and $q_3^G = \frac{1-w(2\lambda-1)-3t}{4}$ and the corresponding profits are $\pi_F^G = \frac{(1-w(2\lambda-1)+t)^2}{16} - G$, $\pi_H^G = \frac{(1-w(3-2\lambda)+t)^2}{16}$ and $\pi_3^G = \frac{(1-w(2\lambda-1)-3t)^2}{16}$.

If Firms F and H merge, the merged firm competes with Firm 3 in country H as Cournot duopolists. The equilibrium outputs and the profit of the merged firm are respectively $q_{F+H}^M = \frac{1-\lambda w+t}{3}$ and $\pi_{F+H}^M = \frac{(1-\lambda w+t)^2}{9} - K$.

If greenfield FDI is the alternative to merger, a merger between firms F and H is profitable if $\pi_{F+H}^M > \pi_F^G + \pi_H^G$, or

$$K < \frac{(1-\lambda w+t)^2}{9} - \left(\frac{(1-w(2\lambda-1)+t)^2}{16} + \frac{(1-w(3-2\lambda)+t)^2}{16} - G\right) \equiv K_5.$$

We get $\frac{\partial K_5}{\partial \lambda} > (<) 0$ for $\lambda < (>) \hat{\hat{\lambda}} = (\frac{9}{7} - \frac{2(1+t)}{7w})$, where $\hat{\hat{\lambda}} < 1$. $\frac{\partial K_5}{\partial \lambda} > 0$ is possible provided $\hat{\hat{\lambda}} > 0$, which happens if $w > \hat{\hat{w}} = \frac{2(1+t)}{9}$. Since we consider $w < \frac{1}{3}$, $w > \hat{\hat{w}}$ is possible if $\frac{2(1+t)}{9} < \frac{1}{3}$, which is satisfied for $w < \frac{1}{3}$ and $t < \frac{1-w}{3}$. Therefore, $\frac{\partial K_5}{\partial \lambda} > 0$ for $\lambda < \hat{\hat{\lambda}}$ and $w > \hat{\hat{w}}$ but $\frac{\partial K_5}{\partial \lambda} < 0$ for $\lambda > \hat{\hat{\lambda}}$ or $w < \hat{\hat{w}}$.

Now consider Firm F's preference for a cross border merger when export is the alternative to merger. Merger between firms F and H occurs if $\pi_{F+H}^M > \pi_F^X + \pi_H^X$, or

$K < \frac{(1-\lambda w+t)^2}{9} - \left(\frac{(1-w(2\lambda-1)-2t)^2}{16} + \frac{(1-w(3-2\lambda)+2t)^2}{16}\right) \equiv K_6.$

We get $\frac{\partial K_6}{\partial \lambda} > (<)0$ for $\lambda < (>)\tilde{\tilde{\lambda}} = \frac{-2-11t+9w}{7w}$, where $\tilde{\tilde{\lambda}} < 1$. $\frac{\partial K_6}{\partial \lambda} > 0$ is possible provided $\tilde{\tilde{\lambda}} > 0$ which happens if $w > \tilde{\tilde{w}} = \frac{1}{9}(2+11t)$. Since we are considering $w < \frac{1}{3}$, $w > \tilde{\tilde{w}}$ is possible if $\frac{1}{9}(2+11t) < \frac{1}{3}$, which happens if $t < \tilde{\tilde{t}} = \frac{1}{11}$.[17] Therefore, $\frac{\partial K_6}{\partial \lambda} > 0$ for $\lambda < \tilde{\tilde{\lambda}}$, $w > \tilde{\tilde{w}}$ and $t < \tilde{\tilde{t}}$ but $\frac{\partial K_6}{\partial \lambda} < 0$ for $\lambda > \tilde{\tilde{\lambda}}$ or $w < \tilde{\tilde{w}}$ or $t > \tilde{\tilde{t}}$.

G Competition in both countries: Under exports, the equilibrium outputs of Firms F and H are $q_F^F = \frac{1-w(2\lambda-1)+t}{3}$, $q_F^H = \frac{1-w(2\lambda-1)-2t}{3}$, $q_H^F = \frac{1-w(2-\lambda)-2t}{3}$ and $q_H^H = \frac{1-w(2-\lambda)+t}{3}$, where the subscripts (superscripts) in these expressions stand for the firms (countries) and the corresponding total equilibrium profits are $\pi_F^X = \frac{(1-w(2\lambda-1)+t)^2+(1-w(2\lambda-1)-2t)^2}{9}$ and $\pi_H^X = \frac{(1-w(2-\lambda)-2t)^2+(1-w(2-\lambda)+t)^2}{9}$.

Now consider the situation under merger. If Firms F and H merge, the equilibrium outputs and the total profit of the merged firm are respectively $q_{F+H}^F = q_{F+H}^H = \frac{1-\lambda w}{2}$ and $\pi_{F+H}^M = \frac{(1-\lambda w)^2}{2} - K$.

Merger between firms F and H occurs if $\pi_{F+H}^M > \pi_F^X + \pi_H^X$, or

$K < \frac{(1-\lambda w)^2}{2} - \left(\frac{(1-w(2\lambda-1)+t)^2+(1-w(2\lambda-1)-2t)^2}{9} + \frac{(1-w(2-\lambda)-2t)^2+(1-w(2-\lambda)+t)^2}{9}\right) \equiv K_7$.

[17] Note that $\tilde{\tilde{t}} = \frac{1}{11}$ is less than the minimum upper limit on t, which is $\frac{2}{9}$ and corresponds to $w = \frac{1}{3}$.

We get $\frac{\partial K_7}{\partial \lambda} > (<)0$ for $\lambda < (>)\hat{\lambda} = \frac{-5-2t+16w}{11w}$, where $\hat{\lambda} < 1$. $\frac{\partial K_7}{\partial \lambda} > 0$ is possible if $\hat{\lambda} > 0$ which happens for $w > \hat{w} = \frac{5+2t}{16}$. Since we are consider $w < \frac{1}{2}$, $w > \hat{w}$ is possible if $\frac{5+2t}{16} < \frac{1}{2}$, which is satisfied for $t < \frac{1-2w}{2}$ for $w < \frac{1}{2}$. Therefore, $\frac{\partial K_7}{\partial \lambda} > 0$ for $\lambda < \hat{\lambda}$ and $w > \hat{w}$ but $\frac{\partial K_7}{\partial \lambda} < 0$ for $\lambda > \hat{\lambda}$ or $w < \hat{w}$.

H Bertrand competition: To solve the Bertrand game, first we obtain the direct demand functions from the inverse demand functions shown in Section 3. They take the following forms:

$$q_F = \frac{(1-\gamma)-P_F+\gamma P_H}{1-\gamma^2} \text{ and } q_H = \frac{(1-\gamma)-P_H+\gamma P_F}{1-\gamma^2}.$$

If Firm F chooses to export, the objective functions for Firms F and H are $\pi_F^X = (P_F - \lambda w - t)q_F$ and $\pi_H^X = (P_H - w)q_H$, respectively. The resulting equilibrium prices, and profits are $P_F^X = \frac{2-\gamma+2\lambda w+\gamma w+2t-\gamma^2}{4-\gamma^2}$, $\pi_F^X = \frac{(2(-1+t+\lambda w)+\gamma-\gamma w-(-1+t+\lambda w)\gamma^2)^2}{(-4+\gamma^2)^2(1-\gamma^2)}$, $P_H^X = \frac{2-\gamma+2w+\lambda\gamma w+t\gamma-\gamma^2}{4-\gamma^2}$ and $\pi_H^X = \frac{(2+(-1+t-\gamma)\gamma+w(-2+\gamma(\lambda+\gamma)^2}{(-4+\gamma^2)^2(1-\gamma^2)}$.

If Firm F undertakes greenfield FDI, the objective functions for firms F and H are $\pi_F^G = (P_F - \lambda w)q_F - G$ and $\pi_H^G = (P_H - w)q_H$ respectively. The resulting equilibrium prices and profits are $P_F^G = \frac{2-\gamma+2\lambda w+\gamma w-\gamma^2}{4-\gamma^2}$, $\pi_F^G = \frac{(2+(-1+w-\gamma)\gamma+\lambda w(-2+\gamma^2))^2}{(-4+\gamma^2)^2(1-\gamma^2)} - G$, $P_H^G = \frac{2-\gamma+2w+\lambda\gamma w-\gamma^2}{4-\gamma^2}$ and $\pi_H^G = \frac{(-2+\gamma+\gamma^2-w(-2+\gamma(\lambda+\gamma)))^2}{(-4+\gamma^2)^2(1-\gamma^2)}$.

Firm F undertakes greenfield FDI if $\pi_F^G > \pi_F^X$, or

$$G < \frac{t(-2+\gamma^2)(-2(-2+t+2\lambda w)+2(-1+w)\gamma+(-2+t+2\lambda w)\gamma^2)}{(-4+\gamma^2)^2(-1+\gamma^2)} \equiv G_2$$

Greenfield FDI vs. cross border merger:

Consider that G < G_2, i.e., greenfield FDI is preferable over export.

If firm F and H merge, the merged firm maximizes the following expression:

$$\pi_{F+H}^{M} = (P_F - \lambda w)q_F + (P_H - \lambda w)q_H - K.$$

The merged firm produces both the products, and the equilibrium prices and the profit of the merged firm are $P_F^M = P_H^M = \frac{(1+\lambda w)}{2}$ and $\pi_{F+H}^{M} = \frac{(-1+\lambda w)^2}{2(1+\gamma)} - K$.

A cross border merger between Firms F and H is profitable compared to greenfield FDI by Firm F if $\pi_{F+H}^{M} > \pi_F^G + \pi_H^G$, or

$$K < \frac{(-1+\lambda w)^2}{2(1+\gamma)} - \left(\frac{\left(2+(-1+w-\gamma)\gamma+\lambda w(-2+\gamma^2)\right)^2}{(-4+\gamma^2)^2(1-\gamma^2)} + \frac{\left(-2+\gamma+\gamma^2-w(-2+\gamma(\lambda+\gamma))\right)^2}{(-4+\gamma^2)^2(1-\gamma^2)} - G\right) \equiv K_8.$$

(i) If $\gamma = 0$, we get that $\frac{\partial K_8}{\partial \lambda} = -\frac{1}{2}w(1-\lambda w) < 0$.

(ii) If $\gamma \in [0,1]$, we get

$$\frac{\partial K_8}{\partial \lambda} = \frac{w[w(8-\gamma(16+\gamma(2+\gamma(-8+\gamma+\gamma^2))))\lambda - (8-\gamma(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4))]}{(4-\gamma^2)^2(1-\gamma^2)}.$$

Since the proof is like Proposition 1, we will be brief here.

We find $w\left[8-\gamma\left(16+\gamma\left(2+\gamma(-8+\gamma+\gamma^2)\right)\right)\right] < [8-\gamma(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4)]$.

We also find $[-8+\gamma(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4)] < 0$ for $w > w' = \frac{(1-\gamma)(2+\gamma)^2(2+(-2+\gamma)\gamma)}{4\gamma(2-\gamma^2)}$. Since we are considering $w < (1-\frac{\gamma}{2-\gamma^2})$, $w > w'$ is possible if $\frac{(1-\gamma)(2+\gamma)^2(2+(-2+\gamma)\gamma)}{4\gamma(2-\gamma^2)} < (1-\frac{\gamma}{2-\gamma^2})$, which happens for $\gamma > \gamma' = (\sqrt{3}-1)$.

If $w > w'$ and $\gamma > \gamma' = (\sqrt{3}-1)$, $\frac{\partial K_8}{\partial \lambda} > 0$ for $\lambda < \lambda' = \frac{-8+\gamma(8(1+w)+\gamma(2+\gamma^2+\gamma^3-4\gamma(1+w)))}{w(-8+\gamma(16+\gamma(2+\gamma(-8+\gamma+\gamma^2))))}$, where $\lambda' < 1$.

Therefore, $\frac{\partial K_8}{\partial \lambda} > 0$ for $\lambda < \lambda'$, $w > w'$ and $\gamma > \gamma'$ but $\frac{\partial K_8}{\partial \lambda} < 0$ for $\lambda > \lambda'$ or $w < w'$ or $\gamma < \gamma'$.

***Export vs. cross border merger*:**

Now assume that G > G_2, i.e., export is Firm F's preferred choice as an alternative to merger.

Cross border merger is profitable compared to export by Firm F if $\pi^M_{F+H} > \pi^X_F + \pi^X_H$, or

$$K < \frac{(-1+\lambda w)^2}{2(1+\gamma)} - \left(\frac{\left(2(-1+t+\lambda w)+\gamma-w\gamma-(-1+t+\lambda w)\gamma^2\right)^2}{(-4+\gamma^2)^2(1-\gamma^2)} + \frac{(2+(-1+t-\gamma)\gamma+w(-2+\gamma(\lambda+\gamma)))^2}{(-4+\gamma^2)^2(1-\gamma^2)}\right) \equiv K_9 .$$

(i) If $\gamma = 0$, we get that $\frac{\partial K_9}{\partial \lambda} = -\frac{1}{2} w(1+t-\lambda w) < 0$.

(ii) If $\gamma \in [0,1]$, we get

$$\frac{\partial K_9}{\partial \lambda} = \frac{w[w\left(8-\gamma\left(16+\gamma\left(2+\gamma(-8+\gamma+\gamma^2)\right)\right)\right)\lambda-(8+2t\left(4-3\gamma^2+\gamma^4\right)-\gamma\left(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4\right)]}{(4-\gamma^2)^2(1-\gamma^2)} .$$

Since the proof is like Proposition 1, we will be brief here.

We find $[w\left(8-\gamma\left(16+\gamma\left(2+\gamma(-8+\gamma+\gamma^2)\right)\right)\right) < (8+2t(4-3\gamma^2+\gamma^4) - \gamma(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4)$.

We also find $[8+2t(4-3\gamma^2+\gamma^4)-\gamma(8(1+w)+2\gamma-4(1+w)\gamma^2+\gamma^3+\gamma^4)] < 0$ for $w > w'' = \frac{(1-\gamma)(2+\gamma)^2(2+(-2+\gamma)\gamma)+2t(4-3\gamma^2+\gamma^4)}{4\gamma(2-\gamma^2)}$. Since we are considering $w < (1-\frac{\gamma}{2-\gamma^2})$, $w > w''$ is possible if $\frac{(1-\gamma)(2+\gamma)^2(2+(-2+\gamma)\gamma)+2t(4-3\gamma^2+\gamma^4)}{4\gamma(2-\gamma^2)} < (1-\frac{\gamma}{2-\gamma^2})$, which happens if $t < t' = \frac{(1-\gamma)(2-\gamma)(2+\gamma)(-2+\gamma(2+\gamma))}{2(4-3\gamma^2+\gamma^4)}$, and it is possible if $t' > 0$, which happens for $\gamma > \gamma'' = (\sqrt{3}-1)$.

If $w > w''$, $t < t'$ and $\gamma > \gamma''$, $\frac{\partial K_9}{\partial \lambda} > 0$ for $\lambda < \lambda'' = \frac{-8(1+t)+\gamma(8(1+w)+\gamma(2+6t+\gamma(\gamma+\gamma^2-2\gamma t-4(1+w)))}{w(-8+\gamma(16+\gamma(2+\gamma(-8+\gamma+\gamma^2))))}$, where $\lambda'' < 1$.

Therefore, $\frac{\partial K_9}{\partial \lambda} > 0$ for $\lambda < \lambda''$, $w > w''$, $t < t'$ and $\gamma > \gamma''$ but $\frac{\partial K_9}{\partial \lambda} < 0$ for $\lambda > \lambda''$ or $w < w''$ or $t > t'$ or $\gamma < \gamma''$.

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