Domestic R&D, Foreign Direct Investment, and Welfare

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Abstract

This paper examines the relation between domestic research and development (R&D) and foreign direct investment (FDI) in addition to its impacts on the domestic welfare in which domestic R&D decisions are endogenized. We show that domestic R&D investment may either increase or decrease a foreign firm's FDI incentives. Further, domestic R&D incentives may always increase regardless of the effects of domestic cost reduction on the foreign firm's FDI decision. We also find that domestic welfare improves under domestic cost reduction if the slope of marginal cost of domestic firms' R&D investment is moderate.

JEL classification: .

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1 Introduction

Foreign direct investment (FDI) has been one of the important ways for the globalization of production in the last few decades.[1] Moreover, it is common that firms in a domestic market that receives FDI also undertake innovations by investing in research and development (R&D). For example, China attracted the largest share of the global investment inflows in 2012 (OECD (2012)), and the levels for R&D investment and innovative activities by China's domestic enterprises have been increasing since the mid-1990s (Jefferson, Bai, Guan, and Yu (2006)). Existing empirical studies have examined the relation between domestic innovative activities and FDI inflows.[2] On

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[1]See Mukherjee and Sinha (2007) and Beladi and Mukherjee (2012) for more details about the significance of FDI on international trade and multinational activities in both developed and developing economies.

[2]See Beladi, Firoozi, and Co (2008) for a recent survey about the mixed empirical effects of domestic R&D on the inflows of FDI.

one hand, Neven and Siotis (1996) find that in the case of US and Japanese FDI into the European Union, respectively, the R&D efforts by the domestic firms are a critical determinant for the FDI inflows. On the other hand, Girma, Gong, and Görg (2008) show a positive effect of FDI on domestic innovations for the privately and collectively owned firms in China. Thus, in this paper, we study the theoretical connection between domestic firms' R&D investment and a foreign firm's FDI decision and the resulting impacts on the domestic welfare.

We consider an international Cournot oligopoly with homogeneous products similar to Beladi and Mukherjee (2012), but the emphasis is on domestic R&D. A foreign firm can choose its production strategy by either exporting or FDI and domestic firms have symmetric constant-returns-to-scale technologies. As for efficiency improvement in terms of cost reduction, domestic firms perform costly R&D activities whereas the foreign firm undertakes FDI. Both of these marginal cost-reducing strategies play a similar role as process innovations. Accordingly, to investigate the stated link, our analysis focuses on the effects of oligopolistic competition on innovations and firms' production efficiency comparison. These arguments are different from those in the existing empirical literature such as entry barriers, technology sourcing and spillovers (e.g. Driffield and Munday (2000) and Love (2003)), whose explanation is limited (Beladi, Firoozi, and Co (2008)).

We show that domestic cost reduction, which is internalized by the domestic firms' R&D decisions, may raise or lower the foreign firm's incentives for FDI depending on the magnitudes of the domestic firms' marginal costs and the foreign firm's marginal cost of exporting. Moreover, we find that domestic firms may always have an incentive to invest in R&D for cost reduction irrespective of its impact on the foreign firm's decision on undertaking FDI. Finally, the analysis of domestic welfare implies that domestic R&D investment can always increase domestic welfare if the slope of marginal cost of domestic firms' R&D investment is moderate.

This paper is closely related to Mukherjee and Sinha (2007) and Beladi, Firoozi, and Co (2008), but there are some important differences. First, although these two papers examine the relation between domestic cost reduction and FDI, Mukherjee and Sinha (2007) and Beladi, Firoozi, and Co (2008) focus on a duopoly market structure in the domestic country, while this paper considers the effects of the number of firms. Additionally, given that FDI acts as a marginal cost-reducing strategy for the foreign firm, domestic cost reduction in Mukherjee and Sinha (2007) is an exogenous process due to technology spillovers from the foreign firm, whereas in our analysis domestic firms also have a cost-reducing strategy through endogenizing their own R&D decisions. Therefore, the focus of this paper is on the interaction among the innovating firm in the technologically frontier country and those in the follower country. Finally, unlike Beladi, Firoozi, and Co (2008) where the foreign firm uses FDI as the only production strategy, the foreign firm in our analysis enters the domestic product market by either exporting or FDI. Hence, the presence of foreign competition considered in Beladi, Firoozi, and Co (2008) and in this paper is different.

The rest of the paper is organized as follows. Section 2 describes the model setup and examines the impact of domestic R&D on FDI. In Section 3, we discuss the changes on the domestic firms' R&D incentives in the presence of foreign competition. Section 4 presents the effect of domestic cost reduction on domestic welfare with the foreign firm's production strategy. Section 5 concludes this study.

2 The Setup

Suppose that there are two countries in this model: a domestic country and a foreign country. In the domestic country, there are $n \geq 1$ firms with identical technology who produce homogeneous goods and compete through Cournot oligopolists. Moreover, there is one firm, denoted by F, in the foreign country who can sell the goods to serve the domestic market either by FDI or export.

Suppose that the foreign firm's marginal cost of production under export is c_x, whereas the marginal cost under FDI is c_f that is assumed to be zero for simplicity, so $c_x > c_f = 0$. The cost difference between the entry modes of the foreign firm can be considered as the per-unit trade cost. Thus, the FDI decision in this study acts as a cost-reducing strategy that affects the gain in the total profit. If FDI is chosen by the foreign firm, it has to incur a fixed cost K.

Assume that the domestic firms' marginal cost is $c > 0$. The domestic firms may be in a country with relatively inferior technology than the country (e.g., the technology frontier) where the foreign firm is located, so the marginal cost of the domestic firms is less than the counterpart of the foreign firm under FDI.

The domestic firms have an option to invest in innovations though R&D, which reduce their marginal cost of production by the effects on marginal profits (e.g., d'Aspremont and Jacquemin (1988) and Sacco and Schmutzler (2011)). Specifically, the domestic firms decrease their marginal cost c by investing the amount of research z. The R&D cost follows the function $\gamma z^2/2$, where γ pins down the convexity of this function and $\gamma > \frac{4}{n+2}$ for analytical convenience. We assume that both the domestic and foreign firms completely protect their cost-reducing strategies so there are no R&D externalities or spillovers across the firms in our analysis.[3]

[3]This assumption is consistent with Beladi, Firoozi, and Co (2008), who specify that technology spillovers have failed to explain the mixed empirical results of the effect of domestic R&D on the inflow of FDI, especially in the case of Japanese multinationals that mainly rely on their own R&D in their home country. There are also no across-firm

We assume that the representative consumer's utility is $u(q,m) = aq - q^2/2 + m$, where $a > 0$ and m is the numeraire good. This utility function generates the domestic inverse market demand function, which is given by

$$P = a - q \tag{1}$$

where P denotes the price and q is the total output of the firms.

Let us consider a 3-stage game. In stage 1, the domestic firms decide whether to invest in R&D or not and choose the subsequent R&D investment if they prefer cost reduction. In stage 2, the foreign firm decides whether it exports or undertakes FDI to enter the domestic market. In stage 3, the firms compete via a Cournot-Nash fashion in the product market. We solve the game by backward induction.

2.1 No R&D Investment in the Domestic Country

Consider the game when the domestic firms do not have incentives to invest in R&D. In this case, if the foreign firm exports, the ith domestic firm where $i = 1, 2, ..., n$ and the foreign firm choose their outputs to maximize the profits respectively as follows:

$$\max_{q_i} (a - q - c)q_i \quad \text{and} \quad \max_{q_F} (a - q - c_x)q_F; \quad i = 1, 2, ..., n. \tag{2}$$

The equilibrium outputs of the ith domestic firm and the foreign firm are given by $q_i^{x*} = \frac{a-2c+c_x}{n+2}$ and $q_F^{x*} = \frac{a+nc-(n+1)c_x}{n+2}$. We assume that $c < \frac{a}{2} \equiv \bar{c}$ and $c_x < \frac{c\gamma n(n+2)+a(\gamma(n+2)-4)}{\gamma(n+1)(n+2)-4} \equiv \overline{c_x}$, which can be checked to ensure the firms' equilibrium outputs to be positive.[4] Hence, the profits of the ith domestic firm and the foreign firm are given by

$$\pi_i^{x*} = \frac{(a - 2c + c_x)^2}{(n+2)^2} \quad \text{and} \quad \pi_F^{x*} = \frac{(a + nc - (n+1)c_x)^2}{(n+2)^2}. \tag{3}$$

However, if the foreign firm undertakes FDI, then the domestic firms and the foreign firm choose their outputs to maximize the profits respectively as follows:

$$\max_{q_i} (a - q - c)q_i \quad \text{and} \quad \max_{q_F} (a - q)q_F - K; \quad i = 1, 2, ..., n. \tag{4}$$

The equilibrium outputs of the ith domestic firm and the foreign firm are given by $q_i^{f*} = \frac{a-2c}{n+2}$

spillovers consideration for the R&D choice by a foreign firm in Mattoo, Olarreaga, and Saggi (2004) or a domestic firm in Mukherjee (2006), both of which use the same convex cost function for R&D investment.

[4] It can be shown that $\overline{c_x}$ is less than $(a + nc)/(n + 1)$ because $a > c$, so that the foreign firm's equilibrium output under exporting in the presence of domestic R&D is positive (i.e., $q_F^{x*} > 0$).

and $q_F^{f*} = \frac{a+nc}{n+2}$, where $c < \bar{c}$ ensures that these outputs are positive. Hence, the profits of the ith domestic firm and the foreign firm are given by

$$\pi_i^{f*} = \frac{(a-2c)^2}{(n+2)^2} \qquad \text{and} \qquad \pi_F^{f*} = \frac{(a+nc)^2}{(n+2)^2} - K. \tag{5}$$

Then, it is straightforward that under no domestic R&D investment, the foreign firm will conduct FDI if $K < \frac{c_x(n+1)(2a+2nc-(n+1)c_x)}{(n+2)^2} \equiv K^N$.

2.2 R&D Investment in the Domestic Country

Consider the game when the domestic firms have incentives for R&D investment. In this case, if the foreign firm exports, then the ith domestic firm and the foreign firm choose their outputs to maximize the profits as follows:

$$\max_{q_i}(a - q - (c - z_i^x))q_i - \frac{\gamma}{2}z_i^{x2} \qquad \text{and} \qquad \max_{q_F}(a - q - c_x)q_F; \quad i = 1, 2, ..., n. \tag{6}$$

Given the domestic R&D investment z_i^x, the equilibrium outputs of the domestic and foreign firms are $q_i^x = \frac{a-2(c-z_i^x)+c_x}{n+2}$ and $q_F^x = \frac{a+n(c-z_i^x)-(n+1)c_x}{n+2}$, respectively. Given these outputs, the foreign firm's profit under exporting is given by $\pi_F^x = \frac{[a-(n+1)c_x+n(c-z_i^x)]^2}{(n+2)^2}$.

However, if the foreign firm undertakes FDI, then the ith domestic firm and the foreign firm choose their outputs to maximize the profits as follows:

$$\max_{q_i}(a - q - (c - z_i^f))q_i - \frac{\gamma}{2}z_i^{f2} \qquad \text{and} \qquad \max_{q_F}(a - q)q_F - K; \quad i = 1, 2, ..., n. \tag{7}$$

The equilibrium outputs of the ith domestic firm and the foreign firm are given by $q_i^f = \frac{a-2(c-z_i^f)}{n+2}$ and $q_F^f = \frac{a+n(c-z_i^f)}{n+2}$, respectively. Given these outputs, the foreign firm's profit under FDI is given by $\pi_F^x = \frac{[a+n(c-z_i^f)]^2}{(n+2)^2} - K$. Hence, in stage 2 where the levels of domestic R&D investment are given, the foreign firm will undertake FDI if $K < \frac{[a+n(c-z_i^f)]^2-[a-(n+1)c_x+n(c-z_i^x)]^2}{(n+2)^2} \equiv K^I$.

Let us move backward to the stage for determining the domestic R&D levels. If $K > K^I$ in which case the foreign firm chooses exporting, then the profit-maximizing R&D level of the ith domestic firm can be computed by

$$\max_{z_i}\left[\frac{a-2(c-z_i)+c_x}{n+2}\right]^2 - \frac{\gamma}{2}z_i^2; \quad i = 1, 2, ..., n.$$

Therefore, the domestic R&D levels and the outputs of the ith domestic firm and the foreign firms in equilibrium are given by $z_i^{x*} = \frac{4(a-2c+c_x)}{\gamma(n+2)^2-8}$, $q_i^{x*} = \frac{\gamma(n+2)(a-2c+c_x)}{\gamma(n+2)^2-8}$ and $q_F^{x*} = \frac{a+n(c-z_i^{x*})-(n+1)c_x}{n+2}$.[5] Substituting z_i^{x*}, q_i^{x*}, and q_F^{x*} into (6) yields the equilibrium profits of the ith domestic firm and the foreign firm under exporting, respectively

$$\pi_i^{x*} = \frac{\gamma(a-2c+c_x)^2}{\gamma(n+2)^2-8} \quad \text{and} \quad \pi_F^{x*} = \frac{[a(\gamma(n+2)-4)+\gamma cn(n+2)-(\gamma(n+2)(n+1)-4)c_x]^2}{(\gamma(n+2)^2-8)^2}. \tag{8}$$

However, if $K < K^I$ in which case the foreign firm chooses FDI, then the profit-maximizing R&D level of the ith domestic firm can be computed by

$$\max_{z_i} \left[\frac{a-2(c-z_i)}{n+2}\right]^2 - \frac{\gamma}{2}z_i^2; \quad i = 1, 2, ..., n.$$

Hence, we derive the equilibrium R&D levels and outputs of the ith domestic firm and the foreign firm as follows: $z_i^{f*} = \frac{4(a-2c)}{\gamma(n+2)^2-8}$, $q_i^{f*} = \frac{\gamma(n+2)(a-2c)}{\gamma(n+2)^2-8}$ and $q_F^{f*} = \frac{a(\gamma(n+2)-4)+\gamma cn(n+2)}{\gamma(n+2)^2-8}$, which are positive given that $c < \bar{c}$, $c_x < \overline{c_x}$ and $\gamma > 4/(n+2)$. Consequently, combining z_i^{f*}, q_i^{f*}, q_F^{f*} and (8), the equilibrium profits for the ith domestic firm and the foreign firm are given by

$$\pi_i^{f*} = \frac{\gamma(a-2c)^2}{\gamma(n+2)^2-8} \quad \text{and} \quad \pi_F^{f*} = \frac{[a(\gamma(n+2)-4)+\gamma cn(n+2)]^2}{(\gamma(n+2)^2-8)^2} - K. \tag{9}$$

Then it is obvious that the threshold of the fixed cost for the foreign firm to conduct FDI under domestic R&D investment becomes $K^I = \frac{c_x(\gamma(n+1)(n+2)-4)[2a(\gamma(n+2)-4)+2\gamma(n+2)nc-(\gamma(n+1)(n+2)-4)c_x]}{(\gamma(n+2)^2-8)^2}$.

2.3 The Impact of Domestic R&D on FDI

Before proceeding to the discussion on the change of domestic R&D incentives in stage 1 responding to the foreign firm's strategy to sell the products, in this subsection, we analyze the effects of the domestic firms' R&D investment on the foreign firm's incentives for FDI.

Denote $c_x^* \equiv \frac{-an(-4+\gamma(n+2)^2)+c(-16(n+1)+\gamma(3n+2)(n+2)^2)}{-8-6n+\gamma(n+1)(n+2)^2}$. Moreover, $c_x^* \geq 0$ if $c \geq \frac{an(-4+\gamma(n+2)^2)}{-16(n+1)+\gamma(3n+2)(n+2)^2} \equiv \underline{c} > 0$ since $n \geq 1$ and $\gamma > 4/(n+2)$,[6] and $c_x^* < \overline{c_x}$ if $c < \frac{a\mathcal{A}}{2\mathcal{B}} \equiv c^*$, where $\mathcal{A} \equiv \gamma^2(n+1)^2(n+2)^3 + 8(5n+4) - 2\gamma(n+2)(3n(2n+5)+8) > 0$, $\mathcal{B} \equiv 32(n+1) + \gamma(n+2)(-16+g(n+1)^2(n+2)^2 - n(11n+28)) > 0$, and $\mathcal{A} < \mathcal{B}$ so $c^* \in (\underline{c}, \bar{c})$.

Then, comparing K^N and K^I gives the following result.

[5] $\gamma > \frac{4}{n+2}$ satisfies the second-order condition and ensures that the domestic R&D levels and the firms' outputs are positive along with $n \geq 1$, $c < \bar{c}$ and $c_x < \overline{c_x}$. In addition, we assume $c > \frac{a}{n+1}$ yielding $\gamma > \frac{4a}{c(n+1)(n+2)}$ by $\gamma > \frac{4}{n+2}$, which ensures $\overline{c_x} < \frac{c\gamma(n+2)^2-4a}{4}$ so $c > z_i^{x*}$.

[6] Notice that this setting satisfies $\underline{c} > a/(n+1)$.

Proposition 1. *(I) If either $c > c^*$ and $c_x < \overline{c_x} < c_x^*$, or $c < c^*$ and $c_x < c_x^*$, then $K^I > K^N$ where domestic R&D investment increases the foreign firm's FDI incentives; (II) If $c < c^*$ and $c_x > c_x^*$, then $K^I < K^N$ where domestic R&D investment decreases the foreign firm's FDI incentives.*

This result provides an explanation for the mixed (i.e., positive and negative) correlations between domestic R&D and FDI inflows without technology sourcing and spillovers, as specified by Beladi, Firoozi, and Co (2008). Domestic R&D investment enhances the domestic firms' competitiveness in the product market by reducing their marginal costs. Given domestic R&D investment, the degree of competition faced by the foreign firm tends to increase since the foreign firm's equilibrium outputs and profits decline. Therefore, cost reduction of the domestic and foreign firms, which plays a similar role as process innovations, leads to the discussion on the relationship between competition and innovations in the existing literature.

First, domestic R&D investment intensifies product market competition. This likely decreases the foreign firm's incentives for undertaking the cost-reducing strategy (i.e., FDI) because as a result of domestic cost reduction, the residual demand that the foreign firm could capture by undertaking FDI is decreased. This hence creates the "Schumpeterian effect", which implies that higher product market competition discourages firms' incentives for innovations by reducing potential postinnovation rents (Schumpeter (1943)).[7] [8] Second, domestic R&D investment increases the foreign firm's incentives for FDI. Because cost reduction induces the domestic firms to steal market shares from the foreign firm, if the foreign firm does not undertake FDI, its competitiveness and residual demand in the product market would decline further. This generates the "escape-competition effect", implying that higher product market competition causes firms to innovate for escaping competition, since with higher competition firms' preinnovation rents decrease by more than their postinnovation rents (Aghion, Bloom, Blundell, Griffith, and Howitt (2005)).[9]

Consequently, when the domestic firms' marginal costs and the foreign firm's counterpart of exporting are relatively close, these firms compete in a "neck-and-neck" (leveled) industry (i.e., Proposition 2 (I)). If the domestic firms invest in R&D, compared to the situation of no R&D investment, they would have a cost advantage over the foreign firm, but the residual demand of the foreign firm does not decrease significantly. Then the escape-competition effect dominates the

[7]The decreasing relation between competition and innovations is shared by models of monopolistic competition and product differentiation (e.g., Dixit and Stiglitz (1977) and Salop (1977)) and models of endogenous Schumpeterian growth (e.g., Grossman and Helpman (1991) and Aghion and Howitt (1992)).

[8]This argument is similar to the positive effect of merger on innovations (i.e., FDI) that is specified in Beladi and Mukherjee (2012).

[9]Beladi and Mukherjee (2012) refer to the increasing relation between competition and innovations as Arrow's "replacement effect" (Arrow (1962)).

Schumpeterian effect, and the foreign firm's incentives for FDI become higher under domestic R&D than no domestic R&D. However, when the domestic firms' marginal costs and the foreign firm's counterpart of exporting are not very close, they are in a less neck-and-neck (unleveled) industry (i.e., Proposition 2 (II)). Then the Schumpeterian effect dominates the escape-competition effect. Consequently, the foreign firm's incentives for FDI become lower under domestic R&D than under no domestic R&D.

3 Changes on Domestic R&D Incentives

This section examines how domestic R&D incentives change in the presence of the foreign firm's FDI decision. The previous analysis indicates $K^N \gtreqless K^I$, depending on the domestic firms' marginal costs and the foreign firm's marginal cost of exporting. Solving the game backward to stage 1 and considering the domestic firms' profits in different subgames, we attain the following proposition.

Proposition 2. *Domestic R&D incentives may always increase irrespective of the effects of the domestic firms' R&D investment on the foreign firm's decision to undertake FDI.*

Proof. Given the production strategy of the foreign firm, we compare the domestic firms' profits in the following cases.

Case 3.1. Suppose that the foreign firm undertakes either exporting or FDI regardless of domestic R&D investment, namely, $K > \max\left\{K^N, K^I\right\}$ or $K < \min\left\{K^N, K^I\right\}$. Then comparing (3) and (7) in Section 2.1, and (5) and (8) in Section 2.2, we know that each domestic firm' profit becomes higher with R&D investment than without R&D investment, which implies that domestic R&D incentives always increase in this case.

Case 3.2. Suppose that domestic R&D investment prevents the foreign firm from undertaking FDI, namely, $K \in (K^I, K^N)$ for $c < c^*$ and $c_x > c_x^*$. Then comparing (5) and (7) shows that the profit of each domestic firm with R&D investment when the foreign firm exports is greater than the counterpart without R&D investment when the foreign firm undertakes FDI, which implies that domestic R&D incentives always increase in this case.

Case 3.3. To investigate how domestic R&D incentives change when the foreign firm's incentives for FDI rise under domestic R&D investment, i.e., $K \in (K^N, K^I)$ for either $c > c^*$ and $c_x < \overline{c_x} < c_x^*$, or $c < c^*$ and $c_x < c_x^*$, we denote $c_x^{**} \equiv (a-2c)\left[\frac{\sqrt{\gamma}(n+2)}{\sqrt{\gamma(n+2)^2-8}} - 1\right]$ and $\tilde{c} \equiv ([an(\gamma(n+2)^2-4) + a(\gamma(n+2)^2(n+1)-6n-8)][(\sqrt{\gamma}(n+2)/\sqrt{\gamma(n+2)^2-8})-1])/([-16(n+1)+\gamma(n+2)^2(3n+2) + 2(\gamma(n+2)^2(n+1)-6n-8)][(\sqrt{\gamma}(n+2)/\sqrt{\gamma(n+2)^2-8})-1])$.

Accordingly, we compare the profit of each domestic firm with R&D investment under FDI by the foreign firm (i.e., $(\gamma(a-2c)^2)/(\gamma(n+2)^2-8)$) and the counterpart without R&D investment under exporting by the foreign firm (i.e., $(a-2c+c_x)^2/(n+2)^2$). This comparison shows that the domestic firms prefer to invest in R&D that attracts FDI by the foreign firm if $c_x < c_x^{**}$. Further, to be consistent with the conditions in Proposition 1, we consider the following two situations:

If $c \in (c^*, \bar{c})$, then FDI-attracting domestic R&D investment (i.e., $K \in (K^N, K^I)$) implies that $c_x < \overline{c_x} < c_x^*$ and $c_x^{**} < \overline{c_x}$. Therefore, domestic R&D incentives increase when $c_x < c_x^{**}$.

If $c \in (\underline{c}, c^*)$, then FDI-attracting domestic R&D investment (i.e., $K \in (K^N, K^I)$) implies $c_x < c_x^*$. Given that $\partial(c_x^* - c_x^{**})/\partial c > 0$, $c_x^* < c_x^{**}$ for $c = \underline{c}$ and $c_x^* > c_x^{**}$ for $c = c^*$, there exists a threshold $\tilde{c} \in (\underline{c}, c^*)$ such that $c_x^{**} < c_x^*$ if $c > \tilde{c}$. Therefore, domestic R&D incentives increase when $c_x < \min\{c_x^*, c_x^{**}\}$.

Hence, we can conclude that when domestic R&D investment attracts the foreign firms to undertake FDI, i.e., $K \in (K^N, K^I)$ for $c \in (\underline{c}, \bar{c})$, domestic R&D incentives always increase if $c_x < \min\{c_x^*, c_x^{**}\}$.

□

The intuition of the above result is as follows. First, if domestic R&D investment does not affect the foreign firm's decision to undertake FDI, in the absence of spillovers, cost reduction enhances the domestic firms' production efficiency to capture more market shares when the foreign firm's marginal cost is given. Then investing in R&D must be the dominate strategy for the domestic firms. This is just a special case in d'Aspremont and Jacquemin (1988) with neither spillovers nor R&D cooperation between the innovating firms.

Second, when the domestic firms' marginal costs are sufficiently small (i.e., $c < c^*$) and the trade cost of exporting is sufficiently high (i.e., $c_x > c_x^*$), domestic R&D investment prevents FDI. This prevention increases the foreign firm's marginal cost and cost reduction induces the domestic firms to further steal the market share from the foreign firm. Consequently, cost reduction strengthens the domestic firms' competitiveness in the product market to a great extent and thus generates incentives for them to undertake R&D investment.[10]

Finally, when the domestic firms' marginal costs are not close to the foreign firm's marginal cost under FDI (which is zero) and the trade cost of exporting is sufficiently small (i.e., $c_x < \min\{c_x^*, c_x^{**}\}$), domestic R&D investment attracts FDI. This attraction reduces the foreign firm's marginal cost and thus reinforces its competitiveness in the product market, which harms the

[10]In this case, domestic R&D investment yields a similar effect on the foreign firm as the domestic merger in Beladi and Mukherjee (2012).

profitability of the non-innovating domestic firms. Hence, cost reduction improves the domestic firms' production efficiency by decreasing their marginal costs and extracting the foreign firm's market share. This effect becomes stronger if the trade cost of exporting is small, yielding incentives for the domestic firms to invest in R&D that reduces their marginal costs.[11]

4 Comparison of Domestic Welfare

Mukherjee and Sinha (2007) claim that a domestic firm's cost reduction may reduce domestic welfare if the foreign firm's production strategy is altered from FDI to exporting. In this section, we analyze the implications of domestic cost reduction through R&D investment on domestic welfare when the domestic R&D decisions are endogenized and the foreign firm's production strategy is taken into account.

First, if domestic cost reduction does not affect the foreign firm's production strategy, then the analysis of domestic welfare is presented by the following two cases.

Case 4.1. Assume that the foreign firm always chooses exporting regardless of domestic cost reduction, namely, $K > \max\left\{K^N, K^I\right\}$ for $c_x \in (0, \overline{c_x})$ and $c \in (\underline{c}, \bar{c})$. Therefore, the domestic welfare under no domestic R&D investment is given by

$$W_N^{x*} = \frac{[a(n+1) - 2c_x - cn]^2 + 2n(a - 2c + c_x)^2}{2(n+2)^2}, \tag{10}$$

whereas the domestic welfare under domestic R&D investment is

$$W_I^{x*} = \left[\begin{array}{c} 2n\gamma(\gamma(n+2)^2 - 8)(a - 2c + c_x)^2 \\ +(4c_x - \gamma(n+2)(c_x + cn) + a(\gamma(n+1)(n+2) - 4))^2 \end{array}\right] / \left[2(\gamma(n+2)^2 - 8)^2\right]. \tag{11}$$

Denote $H = W_I^{x*} - W_N^{x*}$. It can be shown that for $c \in (\underline{c}, \bar{c})$, H is concave in c_x, $H|_{c_x=0} > 0$ and $H|_{c_x=\overline{c_x}} > 0$. Hence, the level of domestic welfare becomes higher under domestic R&D investment compared to under no domestic R&D investment.

Case 4.2. Assume that the foreign firm always undertakes FDI regardless of domestic cost reduction, namely, $K < \min\left\{K^N, K^I\right\}$ for $c_x \in (0, \overline{c_x})$ and $c \in (\underline{c}, \bar{c})$. Therefore, the domestic welfare

[11] See Cheung and Lin (2004) and AlAzzawi (2012) for the positive effects of foreign direct investment on domestic innovations via technology transfer and spillovers in the case of China.

under no domestic R&D investment is given by

$$W_N^{f*} = \frac{2n(a-2c)^2 + [a(n+1) - cn]^2}{2(n+2)^2}, \tag{12}$$

whereas the domestic welfare under domestic R&D investment is

$$W_I^{f*} = \frac{2n\gamma(\gamma(n+2)^2 - 8)(a-2c)^2 + [cn\gamma(n+2) - a(\gamma(n+1)(n+2) - 4)]^2}{2(\gamma(n+2)^2 - 8)^2}. \tag{13}$$

Denote $H = W_I^{f*} - W_N^{f*}$. It can be shown that for $c \in (\underline{c}, \bar{c})$, H is convex in c, and H reaches the minimum level at $c_f^{min} = \frac{a[\gamma(n+2)^2(3n+10)-16(n+5)]}{4[\gamma(n+2)^2(n+4)-4(n+8)]}$, which is greater than $\bar{c}$. Moreover, $H|_{c=\underline{c}} > 0$ and $H|_{c=\bar{c}} = 0$. Hence, the level of domestic welfare becomes higher under domestic R&D investment compared to under no domestic R&D investment.

Next, let us suppose that domestic cost reduction changes the foreign firm's production strategy. Then the analysis of domestic welfare is given by the following two cases.

Case 4.3. Assume that the foreign firm chooses exporting under no domestic R&D while it changes to undertake FDI under domestic R&D. According to Case 3.3, we have $K^N < K < K^I$ for $c_x \in (0, \min\{c_x^*, c_x^{**}\})$ and $c \in (\underline{c}, \bar{c})$ in this case. Therefore, we compare the domestic welfare between under "domestic R&D and FDI by the foreign firm" and under "no domestic R&D and exporting by the foreign firm", namely, (13) and (10). Denote $H = W_I^{f*} - W_N^{x*}$. It can be shown that for $c \in (\underline{c}, \bar{c})$, H is concave in c_x. In addition, $H|_{c_x=0} > 0$, $H|_{c_x=c_x^*} > 0$, and $H|_{c_x=c_x^{**}} > 0$. Hence, the level of domestic welfare becomes higher under domestic R&D investment compared to under no domestic R&D investment.

Case 4.4. Assume that the foreign firm undertakes FDI under no domestic R&D while it chooses exporting under domestic R&D. According to Case 3.2, we have $K \in (K^I, K^N)$ for $c \in (\underline{c}, c^*)$ and $c_x > c_x^*$ in this case. Therefore, we compare the domestic welfare between under "domestic R&D and exporting by the foreign firm" and under "no domestic R&D and FDI by the foreign firm", i.e., (11) and (12). Denote $H = W_I^{x*} - W_N^{f*}$. It can be shown that for $c \in (\underline{c}, \bar{c})$, H is convex in c_x, and H reaches the minimum level at $c_x^{min} = \frac{c\gamma n(4(n-6)+3\gamma(n+2)^2)+a(16-\gamma(\gamma(n-1)(n+2)^2+4(n^2+4)))}{\gamma^2(n+2)^2(2n+1)-8\gamma(3n+2)+16}$. Denote the roots for $H(c)|_{c_x=c_x^{min}} = 0$ as c^{min} and c^{max} where $c^{min} < c^{max}$. Since $H(c)|_{c_x=c_x^{min}}$ is concave in c, if $\gamma \in \left(\frac{4}{n+2}, \bar{\gamma}\right)$, then we find $c^{min} \leq \underline{c} < c^* \leq c^{max}$ so that $H(c)|_{c_x=c_x^{min}} > 0$.[12]

[12] Notice that $\bar{\gamma}$ is the second real solution of a sextic equation with respect to n, which can be computed by *Mathematica*. Further, c^{min}, c^{max} and $\bar{\gamma}$ are available upon request in an unpublished appendix.

Hence, the level of domestic welfare becomes higher under domestic R&D investment compared to under no domestic R&D investment.

In summary, the following result is obtained.

Proposition 3. *Suppose that the slope of marginal cost of domestic firms' R&D investment is moderate, e.g.,* $\gamma \in \left(\frac{4}{n+2}, \bar{\gamma}\right]$*. Then domestic welfare always improves with domestic cost reduction.*

Intuitively, the effect of domestic cost reduction on the domestic welfare depends on whether the foreign firm's production strategy is altered. First, if the foreign firm's production strategy does not change irrespective of domestic cost reduction (i.e., Cases 4.1 and 4.2), it can be shown that domestic firms' R&D investment raises consumer surplus since cost reduction strengthens domestic firms' production efficiency, and then more equilibrium outputs are expected. Moreover, given that the foreign firm's cost efficiency does not change in this circumstance, each domestic firm's profit increases because of its own cost reduction by investing in R&D. As a result, domestic welfare rises unambiguously with domestic cost reduction.

Second, if domestic cost reduction changes the foreign firm's production strategy from exporting to FDI (i.e., Case 4.3), it can be shown that domestic firms' R&D investment raises consumer surplus since both domestic R&D investment and FDI tend to increase the total industry outputs. Moreover, given that the trade cost of exporting is relatively small (i.e., $c_x < c_x^{**}$), the improvement of cost efficiency in the foreign firm by undertaking FDI is not significant, so that cost reduction still helps each domestic firm extract the foreign firm's market share that increases the profit. Thus, domestic welfare rises unambiguously with domestic cost reduction as well.

Finally, if domestic cost reduction changes the foreign firm's production strategy from FDI to exporting (i.e., Case 4.4), it can be shown that with R&D investment, each domestic firm's profit becomes larger because of its own cost reduction and the foreign firm's cost inefficiency, but the change on consumer surplus is indeterminate. On one hand, if consumer surplus increases, then domestic welfare rises unambiguously with domestic cost reduction. On the other hand, if consumer surplus decreases, as γ increases, both the total cost and the marginal cost of the domestic R&D investment would rise, which tend to decrease the equilibrium outputs and the domestic firms' profits. Then, given that $\gamma > 4/(n+2)$ is used to satisfy the second order condition, there exists a upper bound of γ that generates a sufficiently large effect of domestic cost reduction, inducing the domestic firms' profits to just compensate for the potential loss of consumer surplus and therefore a rise in the domestic welfare. Hence, domestic welfare becomes always greater with domestic cost reduction than without domestic cost reduction.

The above result demonstrates that domestic cost reduction could always be welfare-improving for the domestic country even if the foreign firm shifts its production strategy from FDI to exporting. This is due to the fact that domestic cost reduction increases domestic firms' production efficiency, which would sufficiently cover the market's relative cost inefficiency generated by the shift of the foreign firm's production strategy, if the slope of marginal cost of domestic firms' R&D investment is not very high. In contrast to Mukherjee and Sinha (2007), endogenizing the domestic R&D decisions can always help prevent the overall industry inefficiency from being significant, thus raising the domestic welfare. Accordingly, this result suggests that countries that are behind the technology frontier need appropriate policies (e.g., education and research support) to adjust the domestic firms' R&D cost through affecting γ while stimulating domestic innovations and having foreign competition at the same time.

5 Conclusion

This paper internalizes the domestic firms' decisions on cost reduction through R&D in the presence of foreign competition. We provide a rationale through oligopolistic competition and innovations to explain the mixed empirical effects of domestic R&D investment on the foreign firm's incentives for FDI. In addition, we show that domestic R&D incentives may always rise regardless of whether the domestic firms' R&D investment prevents the foreign firm from undertaking FDI or not. Finally, when the slope of marginal cost of domestic firms' R&D investment is moderate, domestic cost reduction can always increase domestic welfare even if the production mode of the foreign firm is changed.

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Unpublished Appendix

In this appendix, we show the derivation for the boundaries of the slope of the marginal cost regarding the domestic R&D investment (i.e., $\bar{\gamma}$) in Case 4.4, so that the domestic welfare always increases with domestic cost reduction when the foreign firm's production strategy is changed from FDI to exporting.

Derivation for Case 4.4

In Case 3.2, we know that the foreign firm undertakes FDI under no domestic R&D while it chooses exporting under domestic R&D if $K \in \left(K^I, K^N\right)$ for $c \in (\underline{c}, c^*)$ and $c_x > c_x^*$. Denoting the domestic welfare difference between these two situations as $H = W_I^{x*} - W_N^{f*}$, we obtain that H is convex in c_x for $c \in (\underline{c}, c^*)$, and H reaches the minimum level at c_x^{min}. In this case, we only need to guarantee $H|_{c_x = c_x^{min}} > 0$ for $c \in (\underline{c}, c^*)$ and $c_x > c_x^*$, then domestic cost reduction always increases the domestic welfare.

Substituting c_x^{min} into H gives a quadratic function of c. Then we find that there exist two roots for $H|_{c_x = c_x^{min}} = 0$, which are denoted by c^{min} and c^{max} where $c^{min} < c^{max}$. Specifically, $c^{min} = \left(\mathcal{M} - \mathcal{N}\right)/\mathcal{D}$ and $c^{max} = \left(\mathcal{M} + \mathcal{N}\right)/\mathcal{D}$, where $\mathcal{M} = an(3\gamma^2(n-1)(n+2)^2 + 16(n+5) - 8\gamma(n(n+9)+2))$, $\mathcal{N} = 4\sqrt{a^2 n(n+2)^2(\gamma + \gamma n - 2)(16 + \gamma^2(n+2)^2(2n+1) - 8\gamma(3n+2))}$, and $\mathcal{D} = n(9\gamma^2 n(n+2)^2 + 16(n+8) - 8\gamma(n(n+18)+8))$. Moreover, $H|_{c_x = c_x^{min}}$ is concave in c. Thus, we need to check if $H|_{c_x = c_x^{min}} > 0$ is an empty set when $(\underline{c}, c^*)$ is within (c^{min}, c^{max}). Finally, we find that in *Mathematica* if the condition that $\gamma \in \left(\frac{4}{n+2}, \bar{\gamma}\right]$ holds, then $(\underline{c}, c^*)$ is within (c^{min}, c^{max}), so that $H|_{c_x = c_x^{min}}$ is always positive.[13]

[13] Note that $\bar{\gamma}$ is given by the second real solution of the sextic equation such that: $\alpha_0 + \alpha_1\gamma + \alpha_2\gamma^2 + \alpha_3\gamma^3 + \alpha_4\gamma^4 + \alpha_5\gamma^5 + \alpha_6\gamma^6 = 0$, where $\alpha_0 = 65536 + 196608n + 196608n^2 + 81920n^3 + 9216n^4$, $\alpha_1 = -196608 - 786432n - 1261568n^2 - 1024000n^3 - 437248n^4 - 89600n^5 - 7680n^6$, $\alpha_2 = 245760 + 1228800n + 2641920n^2 + 3149824n^3 + 2256128n^4 + 984832n^5 + 255040n^6 + 36480n^7 + 2368n^8$, $\alpha_3 = -163840 - 983040n - 2621440n^2 - 4061184n^3 - 4021760n^4 - 2644480n^5 - 1163520n^6 - 337280n^7 - 61792n^8 - 6560n^9 - 320n^{10}$, $\alpha_4 = 61440 + 430080n + 1361920n^2 + 2570240n^3 + 3207424n^4 + 2777344n^5 + 1704000n^6 + 742912n^7 + 227200n^8 + 47232n^9 + 6292n^{10} + 480n^{11} + 16n^{12}$, $\alpha_5 = -12288 - 98304n - 359424n^2 - 794624n^3 - 1184256n^4 - 1255424n^5 - 973184n^6 - 558080n^7 - 236528n^8 - 73088n^9 - 15980n^{10} - 2336n^{11} - 204n^{12} - 8n^{13}$, and $\alpha_6 = 1024 + 9216n + 38144n^2 + 96256n^3 + 165504n^4 + 205184n^5 + 189216n^6 + 131904n^7 + 69876n^8 + 28004n^9 + 8361n^{10} + 1804n^{11} + 266n^{12} + 24n^{13} + n^{14}$.