Domestic R&D, Foreign Direct Investment, and Welfare*

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Abstract

This paper provides a new rationale to examine the two-way relationship between domestic research and development (R&D) and foreign direct investment (FDI), as well as their impacts on domestic welfare. Our analysis is based on the strategic interaction in cost-reducing investment decisions between domestic firms and a foreign firm, which is different from the common factors that are discussed in the literature such as spillovers and technology sourcing. Our results are as follows. We show that domestic R&D investment may either increase or decrease the foreign firm's FDI incentives. Further, depending on the marginal cost of domestic firms, domestic R&D incentives can always increase regardless of the effects of domestic R&D investment on the foreign firm's FDI decision. Finally, we find that domestic welfare improves under domestic cost reduction if the slope of the marginal cost of domestic R&D investment is sufficiently small.

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1 Introduction

Foreign direct investment (FDI) has been one of the most important ways for globalization of production in the last few decades, playing a crucial role in the volume of international trade and multinational activities in both developed and developing economies (Mukherjee and Sinha (2007) and Beladi and Mukherjee (2012)). Moreover, it is commonly observed that firms in an FDI-receiving domestic market undertake innovations by investing in research and development (R&D), which is considered a major approach for countries desiring to improve technology and promote economic growth. For example, China has attracted the largest share of global investment inflows since 2010. The magnitude of these investment inflows increased from 243,703 million USD in 2010 to 258,200 million USD in 2013, which contributed to over 16% of the total world's FDI inflows and approximately equaled those in the European Union (EU) (OECD (2013)). Meanwhile, the levels for R&D investment and innovative activities by China's domestic enterprises have also been increasing since the mid-1990s (Jefferson, Bai, Guan, and Yu (2006)). In particular, a recent study by Wu (2012) indicates that the R&D investment in China grew at an average rate of 17.8% per annum during the period 2001–2011, and the R&D intensity relative to GDP rose considerably from 0.9% in 2000 to 1.83% in 2011. Since many developing countries like China are opening up their economies for international competition and encouraging expenditures on domestic innovations through R&D simultaneously, it is worth analyzing how the decision of foreign firms to conduct FDI is interrelated with the decision of domestic firms to invest in R&D, in addition to the welfare implications induced by this interplay.

Existing empirical studies have devoted efforts examining the two-way relationship between domestic innovative activities and FDI inflows. On the one hand, for example, Kogut and Chang (1991) reveal that in the case of Japanese FDI into the US, the R&D efforts by domestic firms are a critical determinant of FDI inflows.[1] On the other hand, Girma, Gong,

[1] Neven and Siotis (1996) also find a similar result in the case of the US and Japanese FDI into the EU.

and Görg (2009) find a positive effect of sector-level FDI on domestic innovations and R&D for Chinese state-owned enterprises (SOEs) during 1999–2005. Bitzer and Kerekes (2008) also provide evidence in which FDI has a significantly positive impact on domestic R&D capital stock in 10 manufacturing sectors of 17 OECD countries during the period 1973–2000. Consequently, it is shown that a strong empirical connection does exist between domestic firms' R&D investment and a foreign firm's FDI decision. Specifically, these existing empirical studies are usually based on the theoretical background of spillovers and technology sourcing for explanation; domestic firms' R&D increases since they expect to receive technological spillovers from the entry of multinational firms in product competition. The incentive of multinational firms to undertake FDI also rises because it is partially motivated by the spillovers stemming from domestic firms' R&D.

However, it has been shown that the above spillovers-and-sourcing explanation may be limited and incomplete. As for the effect of domestic R&D on FDI, Beladi, Firoozi, and Co (2008) claim that the spillovers argument fails to illustrate the reliance of Japanese multinational enterprises (MNEs) on their own technology in the home country. Using the Swedish firm-level data during 1970–1994, Braconier, Ekholm, and Knarvik (2001) also find a similar result in which there is hardly any evidence for R&D spillovers in the host country transmitted through MNEs' outward FDI. This argument also appears inappropriate because apart from FDI, other direct entry modes (e.g., joint ventures) that may feature spillovers are available for multinational firms. With regard to the effect of inward FDI on domestic R&D, the spillovers-and-sourcing explanation also seems weak for potential diffusion of knowledge. Dunning (1994) argues that inward FDI may not necessarily raise the host country's innovative capacities via spillovers. Therefore, FDI might have no effect, or could even generate a negative effect, on indigenous productivity. Furthermore, using

However, Love (2003) shows that there could exist a positive or negative influence of domestic R&D on FDI in the case of the US.

Taiwanese firm-level data in 1991, Chuang and Lin (1999) show that there is no clear evidence for the spillover effect of FDI on domestic R&D activities. Hence, to abstract our study from the abovementioned factors such as spillovers and technology sourcing, the main purpose of this paper is to seek another channel (i.e., oligopolistic competition) that enables the investigation of the theoretical two-way association between domestic R&D and FDI as well as the resulting impacts on domestic welfare.

To study the relation between domestic R&D and FDI, we conduct a partial equilibrium analysis by employing an international Cournot oligopoly with homogeneous products where domestic firms face a foreign firm's entry; this setup is similar to Beladi and Mukherjee (2012), whose emphasis is on mergers and FDI, while ours is on domestic R&D investment and FDI. We assume that a foreign firm can choose its production strategy by either exporting or FDI and that 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 by incurring a fixed cost as greenfield investment. Both these strategies reduce firms' marginal costs in production and thus serve a similar role as process innovations. Accordingly, to investigate the link between domestic R&D and FDI, our analysis focuses on how oligopolistic competition affects the use of innovations and the comparison of firms' production efficiency. Therefore, our arguments rely on the strategic interaction in cost-reducing investment decisions between domestic firms and the foreign firm, differing from research that addresses the same issue in the empirical literature using spillovers and technology sourcing.

The main results in this study can be summarized as follows. First, we show that domestic R&D investment, which represents the domestic firms' choice on the size of cost reduction, may raise or lower the foreign firm's incentives for FDI depending on the magnitude of the foreign firm's marginal cost of exporting. This result is due to two opposing effects of competition on innovations: higher competition may either increase firms' investment in innovations by capturing more rivals' market shares (i.e., *the escape-competition effect*), or decrease it by reducing firms' potential gains from cost reduction (i.e., *the Schumpeterian effect*). Second, we find that it can be profitable for domestic firms to invest in R&D irrespective of its impact on the foreign firm's FDI decision if the domestic firms' marginal cost is relatively low; investing in R&D reinforces domestic firms' competitiveness and helps extract sufficient market shares from the foreign firm, which increases domestic firms' profitability. Finally, the welfare analysis implies that domestic cost reduction may change the foreign firm's production strategy and in turn affect domestic welfare.[2] If the foreign firm switches from production under FDI to production under exporting, the overall industry cost efficiency could be harmed, followed by welfare losses. However, if the slope of the marginal cost of domestic R&D investment is not very large, the problem of cost inefficiency becomes less severe, thereby making domestic cost reduction beneficial to domestic welfare.

Given that domestic R&D and FDI play a role as process innovations to reduce firms' marginal cost in the presence of oligopolistic competition, this paper is related to the literature discussing the influence of competition on innovations. For example, Vives (2008) and Beladi and Mukherjee (2012) reveal that higher competition may either encourage or discourage firms' investment for process innovations, as shown in our study. Nonetheless, competition in the above papers is induced by the change in either product substitutability or the number of firms. Our analysis differs from theirs by (a) fixing the total number of firms competing in the domestic market and (b) measuring the degree of competition by production efficiency improvement in domestic firms. Thus, the basic features of competition and its effect on the strategic investment decisions of domestic and foreign firms in this paper are different from those in the recent literature.

This paper is also closely related to the studies of Mukherjee and Sinha (2007) and Beladi, Firoozi, and Co (2008), who consider domestic cost reduction and FDI. It is worthwhile

[2] In this study, we use domestic R&D investment and domestic cost reduction interchangeably.

highlighting some differences in the models. First, although these two papers investigate the one-way relationship between domestic cost reduction and FDI, Mukherjee and Sinha (2007) and Beladi, Firoozi, and Co (2008) assume a duopoly market structure in the domestic country, while the current paper focuses on the two-way relationship by studying domestic oligopolies. Additionally, the domestic firm in Mukherjee and Sinha (2007) takes cost reduction as given due to potential technology spillovers from the foreign firm, whereas domestic R&D expenditure in Beladi, Firoozi, and Co (2008) is treated as a parameter for efficiency improvement without profit motivation. Our analysis complements the above studies by allowing domestic firms to make an individual decision on the *profit-maximizing* amount of R&D investment for the size of cost reduction. Given that FDI acts as a cost-reducing strategy for the foreign firm, which is interpreted as an innovating developed-country firm by Beladi and Mukherjee (2012), the main contribution of this paper is to examine how the strategic interaction among innovating firms in a technologically follower country and an innovating firm in an advanced country affects their respective incentives for cost-reducing investment.[3] Finally, unlike Beladi, Firoozi, and Co (2008), where the foreign firm uses FDI as the only production strategy, the foreign firm in our study can choose to enter the domestic product market either by exporting or by FDI. Hence, there is a significant difference between Beladi, Firoozi, and Co (2008) and our study in terms of the presence of foreign competition, which enriches the analysis of the foreign firm's entry mode and the consequences for domestic welfare.

The rest of the paper is organized as follows. Section 2 describes the model setup and derives the two-way relation between domestic R&D and FDI. Section 3 takes account of the foreign firm's production strategy and examines the effect of domestic cost reduction on domestic welfare. Section 4 discusses some potential extensions. Section 5 concludes.

[3]See also Oladi, Beladi, and Chau (2008) for a two-stage duopoly model where spillovers from investment in improving quality (i.e., R&D investment) by a multinational corporation that competes with a local firm increase the quality of exports produced by both firms.

2 The Model

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

Suppose that the foreign firm's marginal cost under export is c_x, whereas the marginal cost under FDI is c_f that is assumed to be zero for simplicity; thus $c_x > c_f = 0$. The cost difference between the entry modes of the foreign firm can be considered as the per-unit trade cost. This trade cost stems from some exogenous conditions such as logistics and transportation, which are unaffected by the foreign firm's actions (e.g., foreign innovations and R&D). Hence, in this study, the FDI decision acts as the only cost-reducing strategy of the foreign firm that influences the gain of its total profit when competing with domestic firms. If the foreign firm chooses FDI, it has to incur a lump-sum fixed cost K as greenfield investment.[4]

Assume that the domestic firms' marginal cost is $c > 0$. The domestic firms are located in a country with relatively inferior technology, whereas the foreign firm belongs to a country with more sophisticated technology (e.g., the technology frontier); thus the marginal cost of the domestic firms is larger than the counterpart of the foreign firm under FDI.

The domestic firms have an option to invest in innovations through R&D, which reduce their marginal cost of production by the effect on marginal profits (e.g., d'Aspremont and Jacquemin (1988)). The domestic firms decrease their marginal cost c by investing in an amount of research z. The R&D cost follows the function $\gamma z^2/2$, where γ pins down the

[4] See Qiu and Wang (2011) for a similar setup where the fixed cost of FDI is used for establishing a new production plant in the domestic country so that the foreign firm can utilize its existing superior technology. Therefore, as the foreign firm's cost-reducing strategy, FDI has a similar role as process innovations.

convexity of this function and satisfies $\gamma > \frac{4}{n+2}$ for computational convenience. In this paper, the domestic firms' cost-reducing strategy is different from the foreign firm's counterpart. The reasons are twofold. First, innovations that advance domestic technology do not originally exist and discovering more of them through R&D is increasingly costly. Second, using an R&D cost function generates an individual technology choice that reduces the marginal cost for each domestic firm through profit maximization, and a quadratic function for R&D costs can ensure that the profit-maximizing level of domestic R&D investment is positive.[5] Further, 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.[6]

Suppose 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 (inverse) demand function in the domestic market, 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 the following game structure, which consists of three stages. In stage 1, the domestic firms decide whether to invest in R&D for reducing the marginal cost. The operation of R&D investment is common knowledge and observable. If a domestic firm prefers cost reduction, it chooses the level of research z accordingly by paying the cost of R&D investment and cost reduction is achieved in the same stage; otherwise, no

[5] As will be seen, for an R&D cost function $v(z_i)$, the second order condition for positive R&D investments is given by $\partial^2\pi_i/\partial z_i^2 = 8(n+2)^2 - v''(z_i) < 0$ regardless of the foreign firm's FDI decision. To satisfy this condition, $v''(z_i)$ must be positive, which implies that the R&D cost function is convex; this can be captured by a quadratic form.

[6] This assumption is consistent with Mattoo, Olarreaga, and Saggi (2004) and Mukherjee (2006), in which there is the no across-firm-spillovers consideration for technology choices by domestic and foreign firms as well as the same convex cost function for improving technology efficiency is used.

R&D investment occurs and the domestic firms' marginal cost does not change. In stage 2, observing the R&D decisions of the domestic firms, the foreign firm makes its decision to enter the domestic market. It can choose either exporting (denoted by x) by having the per-unit trade cost or undertake FDI by having greenfield investment (denoted by f). In stage 3, all 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 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, in the following manner:

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

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 ensure that the firms' equilibrium outputs are positive.[7] 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, in the following manner:

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

[7] It can be checked 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., $q_F^{x*} > 0$).

The equilibrium outputs of the ith domestic firm and the foreign firm are given by $q_i^{f*} = \frac{a-2c}{n+2}$ and $q_F^{f*} = \frac{a+nc}{n+2}$, respectively, where $c < \bar{c}$ ensures that these outputs are positive. Hence, the profits of the ith domestic firm and the foreign firm, respectively, 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 their profits in the following manner:

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

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 profits, respectively, in the following manner:

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

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 domestic R&D levels. For analytical convenience, this study only focuses on a *unique* subgame perfect Nash equilibrium in the sense that a firm strictly prefers one production strategy.[8] If $K > K^I$, in which case the foreign firm chooses exporting, the profit-maximizing R&D level of the ith domestic firm can be computed by

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

This profit maximization problem is equivalent to the optimization problem with an inequality constraint. Since the constraint never binds, complementarity implies that the Lagrangian multiplier is zero. Then 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 $q_F^{x*} = \frac{a+n(c-z_i^{x*})-(n+1)c_x}{n+2}$.[9] 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, the profit-maximizing

[8]This uniqueness ensures that the foreign firm must use one entry mode to serve the domestic market. Hence, the possibility that the foreign firm's payoffs are equal under exporting and FDI, which may cause multiple equilibria, is eliminated. Technically, if the condition $K = K^I$ holds, backward induction implies that in the domestic firms' profit maximization by choosing the R&D levels, the complementary slackness has an equal constraint. This optimization problem significantly complicates the analysis and does not generate new insights into the firms' choice on their strategies.

[9]$\gamma > \frac{4}{n+2}$ satisfies the second-order condition and ensures that the domestic R&D levels and the firms' outputs are positive along with $c < \bar{c}$ and $c_x < \overline{c_x}$. In addition, we assume that $c > \frac{a(2n+3)}{(n+1)(n+2)}$ that yields $\gamma > \frac{4a(2n+3)}{c(n+1)(n+2)^2}$ by using $\gamma > \frac{4}{n+2}$, which sufficiently ensures $\overline{c_x} < \frac{c\gamma(n+2)^2-4a}{4}$; thus $c > z_i^{x*}$.

R&D level of the ith domestic firm can be computed by

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

Hence, by the same logic as previously, 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 $\gamma > \frac{4}{n+2}$. 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, respectively, are given by

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

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 Effect of Domestic R&D on FDI

In this subsection, we investigate the first way of the interplay between the cost-reducing strategies of domestic and foreign firms. We analyze how the domestic firms' R&D investment affects the foreign firm's incentives for FDI into the domestic market.

Let us denote $c_x^* \equiv \frac{-an(-4+\gamma(n+2)^2)+c(-16(n+1)+\gamma(3n+2)(n+2)^2)}{-8-6n+\gamma(n+1)(n+2)^2}$, so that if $c_x > (<) c_x^*$, then $K^N > (<) K^I$. Moreover, it is known that $c_x^* \geq 0$ if $c \geq \frac{an(-4+\gamma(n+2)^2)}{-16(n+1)+\gamma(3n+2)(n+2)^2} \equiv \underline{c} > 0$. To make the lower bound of c always compatible with the positive marginal cost of domestic firms after R&D investment, we assume that there exist a sufficiently large number of domestic firms in the market. This assumption together with $c > \underline{c}$ ensures that for all threshold $c_x^* > 0$, R&D investment does not decrease the domestic firms' marginal cost below zero after cost reduction, given that domestic firms are located in a country with less advanced technology.[10] Also, note that $c_x^* < \overline{c_x}$ if $c < \frac{a\mathcal{A}}{2\mathcal{B}} \equiv c^*$, where $\mathcal{A} \equiv \gamma^2(n+1)^2(n+2)^3 + 8(5n+4) - 2\gamma(n+2)(3n(2n+5)+8) > 0$, $\mathcal{B} \equiv 32(n+1) + \gamma(n+2)(-16+\gamma(n+1)^2(n+2)^2 - n(11n+28)) > 0$, and $\mathcal{A} < \mathcal{B}$. Accordingly, we know that $c^* \in (\underline{c}, \bar{c})$. Then, comparing K^N and K^I yields the following result.

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

Proposition 1 provides an explanation for the mixed (i.e., positive and negative) correlations between domestic R&D and FDI inflows without using spillovers and technology sourcing, as specified by Beladi, Firoozi, and Co (2008). Provided that R&D investment enhances the domestic firms' competitiveness in the product market and FDI plays a similar role as process innovations for the foreign firm, the effect of domestic R&D investment on the FDI decision leads to the discussion on the relationship between competition and innovations in the existing literature.

First, domestic R&D investment intensifies product market competition between the domestic firms and the foreign firm. This is likely to decrease the foreign firm's incentives for adopting 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 very limited. Hence, this creates the "Schumpeterian effect," which implies that higher market competition discourages firms' incentives for innovations by reducing potential post-innovation rents (Schumpeter (1943)).[11] Second, domestic R&D investment increases the foreign firm's in-

[10] In the appendix available upon request, we show that with $\gamma > \frac{4}{n+2}$, $\underline{c} > \frac{a(2n+3)}{(n+1)(n+2)}$ is satisfied if $n \geq 6$. This assumption avoids that $\underline{c} < c < \frac{a(2n+3)}{(n+1)(n+2)}$. In that case, all the positive thresholds of c_x^* that can change the effect of domestic R&D on FDI incentives are captured, but R&D investment may yield a negative marginal cost for domestic firms.

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

centives for FDI. 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 market would decline further. This generates the "escape-competition effect," thereby implying that higher market competition causes firms to innovate, since with higher competition firms' pre-innovation rents decrease more than their post-innovation rents (Aghion, Bloom, Blundell, Griffith, and Howitt (2005)).[12]

Consequently, the coexistence of these two conflicting forces explains the mixed effects of domestic R&D investment on FDI incentives. When the foreign firm's marginal cost of exporting is relatively small, the foreign firm under exporting might either enjoy a cost advantage over the domestic firms or compete in a "neck-and-neck" domestic industry (i.e., Proposition 1 (I)). If the domestic firms invest in R&D, compared to the situation of no R&D investment, the foreign firm's residual demand becomes smaller. Then, using FDI can counteract this impact by improving the foreign firm's competitiveness and making the market competition more severe. In this case, the foreign firm's pre-innovation rents decrease so significantly by domestic R&D that the escape-competition effect dominates the Schumpeterian effect; thus, the foreign firm's incentives for FDI become higher with domestic R&D than without domestic R&D. However, when the foreign firm's marginal cost of exporting is relatively large as compared to the marginal cost of domestic firms, R&D investment already helps the domestic firms capture large market shares, which mainly affect the foreign firm's post-innovation rents (i.e., Proposition 1 (II)). Therefore, undertaking FDI, which strengthens the degree of competition, cannot generate much gain for the foreign firm by increasing its residual demand that is essentially small. This means that domestic R&D does not implies a significant decrease in the foreign firm's pre-innovation rents, such that

[12] Beladi and Mukherjee (2012) refer to the increasing relation between competition and innovations as Arrow's "replacement effect". However, the escape-competition effect specified in Aghion, Bloom, Blundell, Griffith, and Howitt (2005) is more appropriate for this model since it involves two types of competing firms with actions in process innovations (i.e., cost-reducing strategies), which feature changes in the degree of market competition induced by the rivals' innovations.

the Schumpeterian effect dominates the escape-competition effect. Hence, the foreign firm's incentives for FDI become lower with domestic R&D than without domestic R&D.

2.4 Changes in Domestic R&D Incentives

In this section, we reverse our viewpoint by examining how the foreign firm's FDI decision may influence the domestic firms' incentives for R&D in terms of ex-post profits. The previous section indicates that it is possible that $K^N \gtreqless K^I$, depending on c and c_x. Solving the game backward to the R&D stage and comparing the domestic firms' profits in different subgames, we obtain the following proposition.

Proposition 2. *Domestic R&D incentives increase irrespective of the effects of domestic R&D investment on the foreign firm's FDI decision if the marginal cost of domestic firms is sufficiently low.*

The proof is provided in the unpublished appendix. The intuition of the above result can be described as follows. First, if domestic R&D investment does not affect the foreign firm's FDI decision, 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 dominant strategy for the domestic firms to increase profits. This is just a special case of innovating firms in d'Aspremont and Jacquemin (1988) with neither spillovers nor R&D cooperation.

Second, when the marginal cost of domestic firms is not very high ($c < c^*$) and the trade cost of exporting is sufficiently large ($c_x > c_x^*$), domestic R&D investment prevents FDI. This prevention excludes the possibility for the foreign firm to lower its marginal cost, while cost reduction induces the domestic firms to further steal market shares from the foreign firm. Hence, cost reduction strengthens the domestic firms' competitiveness to a great extent in the product market and, thus, generates incentives for them to undertake R&D investment.

Finally, when the trade cost of exporting is not very high (i.e., $c_x < c_x^*$), 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 will harm the profitability of the domestic firms if they do not invest in R&D. Hence, cost reduction improves the domestic firms' production efficiency by decreasing their marginal costs and leaving the smallest proportion of market shares for the foreign firms. This effect is present in our analysis if the trade cost is sufficiently small (i.e., $c_x < c_x^{**}$, in which a domestic firm's profit in (9) is greater than in (3); see c_x^{**} in the appendix). Importantly, this effect gets stronger (i.e., c_x^{**} increases) as the domestic firms' marginal cost becomes smaller (i.e., c is sufficiently low), yielding more incentives for the domestic firms to invest in R&D that minimizes the potential impact of FDI. Of course, if the trade cost is not very small and domestic R&D still encourages FDI (e.g., $c_x \in (c_x^{**}, c_x^*)$), then the above scenario could reverse; following domestic R&D, the market share that the foreign firm can extract from the domestic firms by using FDI is still large, so that the incentives for the domestic firms to undertake R&D decrease. These results could alternatively explain the opposite empirical effect of FDI on domestic R&D in Bitzer and Kerekes (2008).

In summary, domestic R&D incentives increase irrespective of their effect on FDI if the domestic firms' marginal cost is sufficiently low, so that the conditions in the above cases are all satisfied (see, for example, $c < \tilde{c} < c^*$ in the appendix).[13]

Example. Assume that $a = 1$, $n = 10$, and $\gamma = 1$. Thus, $c < 1/2$, $c_x < (1 + 15c)/16 \equiv \overline{c_x}$, $K^N = (11c_x(2 + 20c - 11c_x))/144$, and $K^I = (32c_x(1 + 15c - 8c_x))/289$. Proposition 1 implies that $K^N > (<) K^I$ if $c_x > (<) (2(554c - 175))/379 \equiv c_x^*$, and $c_x^* < \overline{c_x}$ for $c < (5979/12043) = 0.496 \equiv c^*$. Hence, domestic R&D investment increases incentives for FDI if either $c \in (0.496, 0.5)$ or $c < 0.496$ and $c_x < (2(554c - 175))/379$; otherwise, domestic R&D

[13]Specifically, in the appendix it is shown that $c < \tilde{c}$ ensures $c_x^* < c_x^{**}$, so that it is always profitable for the domestic firms to conduct R&D when FDI is attracted.

investment reduces the FDI incentives.

Moreover, we obtain that $\underline{c} = 0.316$ and $\tilde{c} = 0.319$. When domestic R&D prevents FDI, R&D incentives increase if $c \in (0.316, 0.496)$ and $c_x \in ((2(554c - 175))/379, (1 + 15c)/16)$. In contrast, a domestic firm's profit rises by investing in FDI-attracting R&D if $c_x < (3\sqrt{2/17} - 1)(1 - 2c) \equiv c_x^{**}$. According to Proposition 2, when domestic R&D attracts FDI, R&D incentives increase if either $c \in (0.319, 0.5)$ and $c_x < (3\sqrt{2/17} - 1)(1 - 2c)$ or $c \in (0.316, 0.319)$ and $c_x < (2(554c - 175))/379$. In summary, if $c \in (0.316, 0.319)$, it is always profitable for domestic firms to invest in R&D regardless of whether domestic R&D attracts or prevents FDI (i.e, independent of c_x). This outcome suggests that domestic R&D incentives increase if the domestic firms' marginal cost is approximately 31.9% more than the foreign firm's marginal cost under FDI (which is zero).

3 Analysis of Domestic Welfare

Mukherjee and Sinha (2007) argue that if the foreign firm's entry mode is altered from FDI to exporting by a domestic firm's cost reduction, domestic welfare may decline because a large cost inefficiency is caused in the overall industry. Thus, this section takes into account the foreign firm's production strategy and a domestic firm's decision on profit-maximizing R&D investment to analyze the implications of domestic cost reduction on domestic welfare, which is defined as the sum of consumer surplus and domestic firms' profits.[14]

The effect of domestic cost reduction on domestic welfare depends on whether the foreign firm's production strategy is altered since it affects the domestic firms' profits and the underlying consumer surplus. The domestic welfare under "no domestic R&D and exporting

[14]Since this study is built on a partial equilibrium framework in the goods market assuming constant factor prices in other markets, the domestic country's social welfare only includes the total surplus of consumers and local producers. In a general equilibrium setup, domestic welfare is also affected by wages and the labor-supply decision, which depend on competing firms' production strategies. See Oladi, Gilbert, and Beladi (2011) for the impact of FDI on real wages of skilled and unskilled workers in a general equilibrium model with non-traded goods.

by the foreign firm" is

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

while the domestic welfare under "domestic R&D and exporting by the foreign firm" is

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

In addition, the domestic welfare under "no domestic R&D and FDI by the foreign firm" is

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

whereas the domestic welfare under "domestic R&D and FDI by the foreign firm " is

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

Hence, we consider four cases for the effect of domestic cost reduction on domestic welfare: (Case 3.1) domestic cost reduction maintains exporting (i.e., $H_1 = W_I^{x*} - W_N^{x*}$); (Case 3.2) domestic cost reduction maintains FDI (i.e., $H_2 = W_I^{f*} - W_N^{f*}$); (Case 3.3) domestic cost reduction attracts FDI (i.e., $H_3 = W_I^{f*} - W_N^{x*}$); (Case 3.4) domestic cost reduction prevents FDI (i.e., $H_4 = W_I^{x*} - W_N^{f*}$). In the appendix that provides the detailed derivations, we show that there exists an upper bound for γ, which ensures that all the above welfare changes can be positive (i.e., $H_j > 0$ for $j = 1, 2, 3, 4$). This result implies the following proposition.

Proposition 3. *Domestic welfare always improves with domestic cost reduction if the slope of the marginal cost of domestic R&D investment is sufficiently small, i.e.,* $\gamma \in \left(\frac{4}{n+2}, \bar{\gamma}\right)$.

Intuitively, when domestic cost reduction does not change the foreign firm's production strategy (i.e., Cases 3.1 and 3.2) or it changes the foreign firm's production strategy from exporting to FDI (i.e., Case 3.3), it can be shown that domestic firms' R&D investment increases consumer surplus since more total industry outputs are achieved. Moreover, cost reduction helps each domestic firm extract sufficiently large market shares from the foreign firm, which increase the domestic firms' profits. Therefore, the level of domestic welfare rises unambiguously with domestic cost reduction in these situations.

When domestic cost reduction changes the foreign firm's production strategy from FDI to exporting (i.e., Case 3.4), it can be shown that with R&D investment, each domestic firm's profit becomes larger due to its own cost reduction and the foreign firm's relative cost inefficiency (because the marginal cost of exporting is higher than that of FDI), but the change in consumer surplus is indeterminate. On the one hand, suppose that consumer surplus increases. Then, domestic welfare rises unambiguously with domestic cost reduction. On the other hand, suppose that consumer surplus decreases. As γ increases, both the total cost and the marginal cost of domestic R&D investment would rise, which tend to decrease the outputs and profits of the domestic firms. This implies that there exists an upper bound of γ that generates a sufficiently large effect of domestic cost reduction, by which the domestic firms' profits are increased to just compensate for the potential loss of consumer surplus, thereby yielding a rise in domestic welfare.[15] Consequently, under this circumstance, domestic welfare becomes greater with domestic cost reduction than without it.

In contrast to Mukherjee and Sinha (2007) where domestic cost reduction is a result of knowledge spillovers from foreign firms to domestic firms, the above result demonstrates that allowing the domestic firms to determine the size of cost reduction through making their own choices on R&D investment would help prevent the overall industry inefficiency from being significant, thereby raising domestic welfare. Hence, this result suggests that countries that are behind the technology frontier need appropriate policies (e.g., education and research

[15]Note that the condition $\gamma > 4/(n+2)$ in Proposition 3 is used to satisfy the second order condition.

support) to adjust the (marginal) cost of domestic firms' R&D by affecting γ, while these countries stimulate domestic innovations and engage in foreign competition simultaneously.

Nevertheless, if the foreign firm is less efficient in production than what is assumed, undertaking FDI reduces its marginal cost from c_x by exporting to $c_f > 0$ by incurring a fixed cost. Then, the foreign firm also has to pay a variable cost for FDI and the threshold value for the foreign firm to conduct FDI becomes $K^N = \frac{(c_x - c_f)(n+1)(2a+2nc-(n+1)(c_x+c_f))}{(n+2)^2}$ under no domestic R&D and $K^I = \frac{(c_x-c_f)(\gamma(n+1)(n+2)-4)[2a(\gamma(n+2)-4)+2\gamma(n+2)nc-(\gamma(n+1)(n+2)-4)(c_x+c_f)]}{(\gamma(n+2)^2-8)^2}$ under domestic R&D, respectively. Moreover, the threshold value of the marginal cost of exporting that pins down the effect of domestic R&D on FDI becomes $c_x^* = \frac{-an(-4+\gamma(n+2)^2)+c(-16(n+1)+\gamma(n+2)^2(3n+2))}{-8-6n+\gamma(n+1)(n+2)^2} - c_f$. It is obvious that $\frac{\partial K^N}{\partial c_f} < 0$, $\frac{\partial K^I}{\partial c_f} < 0$ and $\frac{\partial c_x^*}{\partial c_f} < 0$, implying that given the same levels of K and c_x, the foreign firm engages in FDI only if it is from a country with more productive technology. In this circumstance, Case 3.1 is more likely to occur when c_f becomes larger. Thus, this outcome provides a different welfare implication for the domestic country: with the entry of firms from less technologically advanced countries, fewer government interventions in the cost of R&D investment are required for domestic cost reduction to be welfare-enhancing. Of course, a larger c_f may change Case 3.2 to Case 3.4, which still needs the government's support on domestic R&D to make cost reduction improve welfare.

4 Discussion

Cross-border Merger. This model assumes only one FDI form: greenfield investment. Qiu and Wang (2011) consider another FDI form: brownfield investment, such that the foreign firm uses its own technology (i.e., $c_f = 0$) by building a joint venture with a local firm through a cross-border merger. The foreign firm's share of profits from the joint venture can be influenced by the local government's FDI policy.

If a cross-border merger also becomes an option for the foreign firm's entry mode, there will be one additional threshold value for the foreign firm to choose between FDI and merger given the domestic firms' R&D decision (e.g., K^{NM} without domestic R&D and K^{IM} with domestic R&D). Domestic R&D may either increase or decrease the foreign firm's incentives for one entry mode, depending on the comparison of the thresholds' values. Nonetheless, the foreign firm benefits from a merger due to the reduction in the number of local competitors. Thus, following Qiu and Wang (2011), the incentives for a merger are likely to decline as compared to FDI and export (i.e., K^{NM} and K^{IM} are sufficiently large for choosing FDI and the foreign firm's profit is smaller under a merger than under exporting) when the market demand is low (i.e., a is small), domestic competitors are weak (i.e., c is large), domestic competition is essentially lax (i.e., n is large), and the trade cost is small (i.e., c_x is small); otherwise, a merger would be preferred. In practice, developing countries generally impose a restricted FDI policy to limit the foreign equity share of joint-venture entities, which also abates the incentives for a cross-border merger (UNCTAD (2000)). In the above cases, the focus of the foreign firm's entry decision would be consistent with our current study (which is still between export and FDI), and our analysis of the strategic investments between the domestic firms and the foreign firm would continue to hold.

Dynamic R&D Investment. Our model is based on a static analysis in which R&D investment reduces marginal cost instantaneously. However, Cellini and Lambertini (2005) consider dynamic R&D for process innovations in an oligopoly market. Cost reduction takes periods to accomplish, and a domestic firm's marginal cost decreases in each period according to the marginal cost and R&D investment in the previous period.[16] In the steady state, the level of R&D investment is decreasing in the number of domestic firms. Fewer competitors tend to increase profits and the funds available to any given firm for undertaking R&D activities. As a result, the steady-state marginal cost, which also depends on n, becomes

[16] See also Beladi, Firoozi, and Co (2008) for the effect of domestic R&D on FDI inflows in a two-period model where domestic firms' R&D spending in period one improves the efficiency of production in period two.

lower. In addition, when c_x^* is decreasing in n in our model, Proposition 1 implies that domestic R&D is more likely to raise the foreign firm's incentives for FDI with a smaller n, which increases consumer surplus. If the efficiency improvement of FDI for the foreign firm is insignificant, fewer competitors would improve domestic welfare due to higher levels of domestic firms' profits and consumer surplus, as in Case 3.3. This prediction is consistent with the experience of China in the past decade when both domestic R&D and FDI inflows rose in the presence of relatively low competition (Qiu and Wang (2011)). Hence, this outcome suggests that dynamics would play an important role in the relationship between competition and domestic R&D.

General Demand. We so far have assumed that the demand function is linear, yielding closed-form solutions for outputs, R&D investments, and profits of the firms. This setting simplifies the analysis and allows us to study the two-way relation between domestic R&D and FDI in addition to the consequences for domestic welfare. However, the demand function in reality may be nonlinear as some literature suggests (e.g., Vives (2008)). A less elastic residual demand facing a domestic firm is likely to increase the levels of outputs and R&D investments. This would change the threshold value c_x^* for the influence of domestic R&D on the foreign firm's FDI decision, because the demand function alters the net impact of the Schumpeterian effect and the escape-competition effect. Also, the implication of domestic R&D incentives would be different, but it will still be determined by the domestic firms' marginal cost as in Proposition 2. Future research should extend this model to include an analysis of the general-demand setting to examine the link between domestic R&D and FDI.

5 Conclusion

This study explores the relationship between the domestic firms' decisions on cost reduction through R&D and a foreign firm's decision on FDI, as well as the influences on domestic welfare. We first provide a rationale through oligopolistic competition and innovations to explain the mixed empirical effects of domestic R&D on the foreign firm's FDI incentives. In addition, we show that depending on the marginal cost of domestic firms, domestic R&D incentives could rise regardless of whether domestic R&D prevents FDI. Finally, domestic R&D may change the foreign firm's entry mode from FDI to exporting, which causes cost inefficiency in production. Nevertheless, if the slope of marginal cost of domestic R&D investment is relatively small, domestic cost reduction can counteract the impact of the industry cost inefficiency and always enhance domestic welfare. This result implies that when developing countries encourage both domestic innovations and competition with foreign firms' participation from developed countries, policies must be designed wisely to ameliorate the research environment for domestic firms in order to reduce their (marginal) cost of R&D investment.

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