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Intellectual property rights, southern
innovation and foreign direct investment

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ABSTRACT

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Key Words: Foreign direct investment; Innovation; Patent protection

JEL Classifications: F12, F13, O32, O34

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Intellectual property rights, southern innovation and foreign direct investment

1. Introduction

A fascinating development in recent decades is the dominance of foreign direct investment (FDI) over international trade (UNCTAD, 2006), which has generated a vast theoretical and empirical literature on FDI.¹ A factor which is often considered to be an important determinant of FDI is the protection of intellectual property rights. Since the developed-country firms make use of their intellectual-property related assets under FDI, it is generally believed that a stronger patent regime in the host country encourages inward FDI by protecting the intellectual-property related assets of the investors. Since the inception of the Uruguay round of the General Agreement on Tariffs and Trade, developing countries are increasingly urged to strengthen their patent regimes in order to standardize the patent regime across the world, thus trying to protect the intellectual properties of the developed-country firms.

Empirical evidence is however mixed on the effects of patent protection on FDI. The empirical studies by Lee and Mansfield (1996), Maskus (1998) and Smarzynska (2004) show a positive relationship between patent protection and FDI, while there are other works showing either a negative (see, Yang and Maskus, 2001, Pfister and Deffains, 2005) or an insignificant (see, Seyoum, 1996 and Fosfuri, 2004) relationship between these two. In these works, technology licensing is identified as the reason for lower inward FDI following a stronger Southern patent regime. Nunnenkump and Spatz (2004) show that industry as well as the host-country characteristics play important roles in determining the relationship between FDI and patent.

¹ See, Saggi (2002) for a recent survey on FDI.

Using a simple model of international oligopoly with product innovation, we show that whether a stronger patent protection in the developing country increases a developed-country firm's incentive for inward FDI depends on the innovative capability of the developing-country firm. More specifically, we show that if either the cost of Southern (or developing-country) innovation is sufficiently low such that the Southern firm innovates irrespective of the Southern patent regime and the production strategy of the Northern (or developed-country) firm, or the Southern firm's cost of innovation is moderate such that it innovates only under a strong Southern patent regime, a stronger Southern patent regime may reduce the Northern firm's incentive for FDI. For all other costs of Southern innovation, a stronger Southern patent regime increases the Northern firm's incentive for FDI. Thus, our paper acts like a caution and shows that a blanket approach for strengthening Southern patent protection in order to attract inward FDI may not be justifiable, if the innovative capability of the Southern firm is high.

If the Southern firm innovates irrespective of the Southern patent regime and the production strategy of the Northern firm, a strong Southern patent regime reduces the number of products produced by the Northern firm by preventing knowledge spillover. If the products are sufficiently differentiated, the reduced product range of the Northern firm under a strong Southern patent regime may reduce the Northern firm's net benefit from FDI over exporting compared to a weak Southern patent regime. In this situation, a strong Southern patent regime may reduce the Northern firm's incentive for FDI.

If the Southern firm innovates only under a strong Southern patent regime, the number of products produced by the Northern firm is not affected by the Southern patent regime. However, a stronger Southern patent regime helps to increase the profit of the Northern firm under both FDI and exporting by reducing the intensity of competition between the firms, since the degree

of product differentiation is higher under the strong patent regime. If the products are not very much differentiated and the output distortion created under exporting due to the transportation cost is not very high, the Northern firm's net benefit is higher under the strong patent regime. As a result, a strong Southern patent regime reduces the Northern firm's incentive for FDI compared with the weak Southern patent regime.

While knowledge spillover is prominent in the Southern countries, empirical evidence shows considerable innovative activities in many developing and newly industrialized countries. Significant amount of innovation can be found in many Asian countries such as South Korea, India, China and Taiwan. Correa (1990) presents the main characteristics of the software industry in Latin America while discussing development and commercialization of software in many Latin American countries. Significant innovative activities are evidenced in Indian pharmaceutical industry (The Financial Express, December 13, 2004).² Tsai and Wang (2004) provide evidence of significant innovative activities in Taiwan's electronics industry. Wei et al. (2008) provide the evidence of innovation by Chinese motorcycle companies. The importance of innovation in less developed countries is also acknowledged in Muniagurria and Singh (1997), Zhou et al. (2002) and Chen and Puttitanun (2005).

Even if the innovative activities of many developing and newly industrialized countries have started to attract attention of the researchers, the literature on patent protection is yet to show its implications on inward FDI. To the best of our knowledge, this is the first paper that considers the implications of Southern innovation in determining the effects of Southern patent regime on the incentive for inward FDI by the Northern firm.

² Rajesh Unnikrishnan reports, "Domestic giant Ranbaxy Laboratories tops the list of companies from developing nations in filing patents. The company has filed patents for 240 products. The move assumes significance as the product patent regime comes into force next month. According to the Patent Cooperation Treaty (PCT) database, Indian drug companies have filed around 4,200 applications. Of these, 55% are for pharmaceutical innovations".

In a theoretical paper, Glass and Saggi (2002) show that a stronger patent protection in the South absorbs more Southern resources for imitation, thus crowding out inward FDI, which, in turn, moves resources in the North from innovation to production and reducing Northern innovation. Hence, in their analysis, higher cost of imitation in the South and lower Northern innovation are responsible for the FDI reducing effect of a stronger Southern patent regime. In contrast, the innovative activity of the Southern firm is the key factor for our results. We consider that knowledge spillover (or imitation) is costless and a stronger Southern patent protection reduces the degree of knowledge spillover exogenously (as in Helpman, 1993 and Lai, 1998).³ Thus, we abstract our analysis from the resource effect considered in Glass and Saggi (2002), and show the roles played by Southern innovation.

In an earlier work, Helpman (1993) shows that a stronger Southern patent regime increases the products of the Northern multinationals. Lai (1998) shows that a stronger Southern patent regime encourages FDI by Northern firms. However, unlike our paper, both these papers ignore Southern innovation, which is the key factor in our analysis.

Our paper falls in the area of the theoretical literature analyzing the effects of the patent regime in a North-South trading environment (see, e.g., Chin and Grossman, 1990, Segerstrom *et al.*, 1990, Diwan and Rodrik, 1991, Grossman and Helpman, 1991, Deardorff, 1992, Taylor, 1994, Vishwasrao, 1994, Fosfuri, 2000, Markusen, 2001 and Sinha, 2006). However, a common feature of those works is to ignore the impact on FDI, which is the main focus of this paper.

³ The switch from the process patent regime to product patent regime in many developing countries such as in India may justify this assumption. While process patent allows the imitator to produce a product similar to that of the innovator by using a different production process, product patent completely prevents the imitator to produce the product of the innovator. Hence, in our analysis, the stronger patent protection can be viewed as an approximation for the product patent regime, while the weaker patent system can be viewed as an approximation for the process patent regime.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 determines the equilibrium R&D decision of the Southern firm. Section 4 shows the effects of the Southern patent regime on the Northern firm's FDI decision. Section 6 concludes. The proofs are relegated to the appendix.

2. The Model

Consider two countries, called North and South. Assume that there is a firm in each of North and South and call the firms as N and S respectively. For simplicity, we assume that at the beginning of the game neither firm has any technology to produce a good. However, the firms can invent new technologies.

Let firm N targets to invent product x , while firm S targets to invent product y . We consider that the products x and y are imperfect substitutes.⁴ We assume that each firm can invent a single product at one point of time, which implies a restriction on the R&D capacity of the firms.⁵ Since x and y are imperfect substitutes, each firm would prefer to invent the technology which is different from its competitor.⁶

Assume that firm N is more capable in doing innovation and requires lower R&D investment. We assume that the R&D investment of firm N is $R_N \geq 0$ and firm S needs to spend

⁴ The assumption of imperfect substitutes can be consistent with a strong patent if we consider that the degree of substitutability depends on the tastes and preferences of the consumers. For example, even if the manual typewriter is different from the electronic typewriter or computer, these products may be imperfect substitutes depending on the tastes and preferences of the consumers. Evidences can also be found from the pharmaceutical industry where two different drugs can solve some common problems. For example, both Zantac and Gaviscon solve the problem of acidity, and become substitutes.

⁵ In real world, we don't find one firm is investing in all the products. This may be due to strategic reasons, or may be due to physical or financial constraints on R&D. We assume the latter and consider that each firm can invent a single product at any point of time.

⁶ There may be a coordination problem in the R&D stage, i.e., which firm will invent which technology. However, the flow of information at the R&D stage and slight early investment of one firm may solve this coordination problem. We assume away this coordination problem by considering a pre-determined choice of technology development, since the coordination problem does not add anything to the main purpose of this paper.

R amount more than firm N , where $R > 0$. The cost of R&D to firm S is then $R_S = R_N + R$. This is consistent with the previous works where the firms in the developed countries do R&D at a lower cost, which reflect their higher capabilities in R&D, and are more prone to innovation (see, e.g., Muniagurria and Singh, 1997, Zhou et al., 2002 and Chen and Puttitanun).⁷ To economize on the notation, we normalize the cost of R&D of firm N to 0. This simplification will not affect our analysis as long as firm N innovates in equilibrium.

We will consider two types of patent regimes in the South: a weak patent protection and a strong patent protection. Under a strong patent protection in the South, only the patent holder of the product can sell its product in the Southern market. However, there is knowledge spillover under a weak patent protection in the South. Hence, under this patent regime, knowledge spillover helps both firms to produce the same product.

We assume that both firms are symmetric with respect to knowledge spillover and, for simplicity, we assume that knowledge spillover is costless. Our results will hold even if knowledge spillover is costly but it is an equilibrium outcome under a weak patent regime.

Assume that the firms compete in the Southern market. The representative consumer's utility depends on the consumption of x , y and a numeraire good m , and it is given by

$$U(x, y) + m \text{ with } U(x, y) = a(x + y) - \frac{x^2}{2} - \frac{y^2}{2} - \gamma xy, \text{ where } \gamma \text{ shows the degree of product}$$

differentiation.⁸ The products are perfect substitutes for $\gamma = 1$, and they are isolated for $\gamma = 0$.

Since we consider the goods x and y as different, we concentrate on $\gamma \in [0, 1)$.

⁷ As documented in Chen and Puttitanun (2005), "during 1985-1995, the number of [patent] applications was 2757 in Brazil, 1545 in India, 5549 in South Africa, and 59249 in South Korea; as compared to 9325 in Australia, 3039 in Canada, 335061 in Japan, and 127476 in the US during the same period."

⁸ This utility function is due to Bowley (1924), and is typical in the literature (see, e.g., Singh and Vives, 1984). Note that $x = x_N + x_S$ ($y = y_N + y_S$), and x_N and x_S (y_N and y_S) are the outputs of x (y) by firms N and S respectively.

The inverse market demand functions for x and y are respectively

$$P_x = a - x - \gamma y, \quad (1a)$$

$$P_y = a - y - \gamma x, \quad (1b)$$

where P_x and P_y are prices of x and y . For simplicity, we normalize the marginal costs of production for both x and y to zero. We also assume that there are no other costs related to production and innovation.

We assume that firm N may either relocate its production to the Southern country (called FDI), or produce in the North and export to the south. FDI requires a fixed investment, F ,⁹ while exporting by firm N involves a transportation cost, t . In order to avoid corner solutions, we assume that t is low enough to ensure positive outputs by firm N . For our analysis, it will mean

$$t < \frac{a}{2}. \quad (2)$$

We consider the following game. At stage 1, firm N decides whether to export or to undertake FDI. At stage 2, the firms take decisions on R&D. Given our assumption that the R&D cost of firm N is 0, firm N will always do R&D. Therefore, the R&D decision is effectively for firm S only. At stage 3, knowledge spillover occurs if there is a weak patent regime. At stage 4, the firms compete in the product market like Cournot duopolists. We solve the game through backward induction.

⁹ F captures all the start-up costs of a new plant, including the adjustment cost of learning to operate in a new institutional and financial environment.

3. R&D decision of the firms

3.1. A strong Southern patent regime

First consider the game under a strong Southern patent regime. There is no knowledge spillover in this situation.

Consider the situation under exporting by firm N . If firm S does not innovate, i.e., only firm N produces, the equilibrium outputs of firm N can be found as $\left(\frac{a-t}{2}\right)$, and its profit is

$$\Pi_N^{\text{E}^{\text{strong (NI)}}} = \left(\frac{a-t}{2}\right)^2. \quad (3)$$

However, if firm S innovates, so that firms N and S compete in the product market, the equilibrium outputs of firms N and S can be found, respectively, as $x_N^{\text{E}^{\text{strong (I)}}} = \frac{a(2-\gamma)-2t}{(4-\gamma^2)}$ and

$y_S^{\text{E}^{\text{strong (I)}}} = \frac{a(2-\gamma)+\gamma t}{(4-\gamma^2)}$. The equilibrium profits of the firms are

$$\Pi_N^{\text{E}^{\text{strong (I)}}} = \left[\frac{a(2-\gamma)-2t}{(4-\gamma^2)}\right]^2 \quad \text{and} \quad \Pi_S^{\text{E}^{\text{strong (I)}}} = \left[\frac{a(2-\gamma)+\gamma t}{(4-\gamma^2)}\right]^2 - R. \quad (4)$$

Therefore, if there is a strong Southern patent protection and firm N exports, firm S innovates if

$$R < \left[\frac{a(2-\gamma)+\gamma t}{(4-\gamma^2)}\right]^2 \equiv R_{\text{Export}}^{\text{strong}}. \quad (5)$$

Now consider the situation under FDI by firm N . If firm S does not innovate, the equilibrium outputs of firm N can be found as $\left(\frac{a}{2}\right)$ and its profit is

$$\Pi_N^{F^{strong(N)}} = \left(\frac{a}{2}\right)^2 - F. \quad (6)$$

However, if firm S innovates, the equilibrium outputs of firms N and S can be found, respectively, as $x_N^{F^{strong(I)}} = \frac{a}{(2+\gamma)}$ and $y_S^{F^{strong(I)}} = \frac{a}{(2+\gamma)}$. The equilibrium profits of the firms

are

$$\Pi_N^{F^{strong(I)}} = \left[\frac{a}{(2+\gamma)}\right]^2 - F \quad \text{and} \quad \Pi_S^{F^{strong(I)}} = \left[\frac{a}{(2+\gamma)}\right]^2 - R. \quad (7)$$

Therefore, if there is a strong Southern patent protection and firm N undertakes FDI, firm S innovates if

$$R < \left[\frac{a(2-\gamma)}{(4-\gamma^2)}\right]^2 \equiv R_{FDI}^{strong}. \quad (8)$$

The following result follows immediately from (5) and (8).

Lemma 1: $R_{FDI}^{strong} < R_{Export}^{strong}$.

3.2. A weak patent regime

Weak patent protection in the South creates knowledge spillover, which allows the imitator to produce a perfect substitute of the innovator's product at a marginal cost similar to that of the innovator.¹⁰

¹⁰ We consider two extreme situations of knowledge spillover in our analysis. As an alternative to no knowledge spillover under a strong patent system, the marginal cost of production of the imitator, which gets the benefit of knowledge spillover, can be considered to be very high so that production of the imitated product is unprofitable. In contrast, the marginal costs of production of the innovator and the imitator are the same under a weak patent protection. One can easily generalize this situation by assuming that the marginal cost of the imitator under a weak patent protection is non-prohibitive but it is higher than that of the innovator. This generalization will not eliminate

Note that we have assumed that knowledge spillover occurs irrespective of export and FDI by firm N . Though a more general approach would perhaps consider that knowledge spillover would be more effective under FDI than under export, might be because of the distance between the firms, it must be clear that this situation would make FDI more likely under a strong Southern patent protection by reducing knowledge spillover under FDI. However, we assume away this bias on knowledge spillover under export and FDI.

First, consider exporting by firm N . If firm S does not innovate, the equilibrium outputs of firms N and S are respectively $x_N^{E\text{-weak(NI)}} = \left[\frac{a-2t}{3} \right]$ and $x_S^{E\text{-weak(NI)}} = \left[\frac{a+t}{3} \right]$. The equilibrium profits of the firms are

$$\Pi_N^{E\text{-weak(NI)}} = \left[\frac{a-2t}{3} \right]^2 \quad \text{and} \quad \Pi_S^{E\text{-weak(NI)}} = \left[\frac{a+t}{3} \right]^2. \quad (9)$$

However, if firm S innovates, the equilibrium outputs of firms N and S are respectively

$$x_N^{E\text{-weak(I)}} = \frac{a-2t}{3(1+\gamma)}, \quad x_S^{E\text{-weak(I)}} = \frac{a+t}{3(1+\gamma)}, \quad y_N^{E\text{-weak(I)}} = \frac{a-2t}{3(1+\gamma)} \quad \text{and} \quad y_S^{E\text{-weak(I)}} = \frac{a+t}{3(1+\gamma)}. \quad \text{The equilibrium}$$

profits of the firms are

$$\Pi_N^{E\text{-weak(I)}} = \frac{2(a-2t)^2}{9(1+\gamma)} \quad \text{and} \quad \Pi_S^{E\text{-weak(I)}} = \frac{2(a+t)^2}{9(1+\gamma)} - R. \quad (10)$$

Therefore, if there is a weak patent protection in the Southern country and firm N exports, firm S innovates if

$$R < \frac{2(a+t)^2}{9(1+\gamma)} - \left[\frac{a+t}{3} \right]^2 \equiv R_{Export}^{\text{weak}}. \quad (11)$$

the negative relationship between patent protection and FDI as long as the marginal cost difference between the innovator and the imitator is not very high under a weak patent system. To keep the matter simple without losing any important insight, we assume that the marginal costs of the firms are the same under knowledge spillover.

Now look at the situation under FDI by firm N . If firm S does not innovate, the equilibrium outputs of firms N and S are respectively $x_N^{F^{weak}(NI)} = \left[\frac{a}{3}\right]$ and $x_S^{F^{weak}(NI)} = \left[\frac{a}{3}\right]$. The equilibrium profits of the firms are

$$\Pi_N^{F^{weak}(NI)} = \left[\frac{a}{3}\right]^2 - F \quad \text{and} \quad \Pi_S^{F^{weak}(NI)} = \left[\frac{a}{3}\right]^2. \quad (12)$$

However, if firm S innovates, the equilibrium outputs of firms N and S are respectively $x_N^{F^{weak}(I)} = \frac{1}{3} \frac{a}{(1+\gamma)}$, $x_S^{F^{weak}(I)} = \frac{1}{3} \frac{a}{(1+\gamma)}$, $y_N^{F^{weak}(I)} = \frac{1}{3} \frac{a}{(1+\gamma)}$ and $y_S^{F^{weak}(I)} = \frac{1}{3} \frac{a}{(1+\gamma)}$. The

equilibrium profits of the firms are

$$\Pi_N^{F^{weak}(I)} = \frac{2a^2}{9(1+\gamma)} - F \quad \text{and} \quad \Pi_S^{F^{weak}(I)} = \frac{2a^2}{9(1+\gamma)} - R. \quad (13)$$

Therefore, if there is a weak patent protection in the Southern country and firm N undertakes FDI, firm S innovates if

$$R < \frac{2}{9} \frac{a^2}{(1+\gamma)} - \frac{a^2}{9} \equiv R_{FDI}^{weak}. \quad (14)$$

The following result follows immediately from (11) and (14).

Lemma 2: $R_{FDI}^{weak} < R_{Export}^{weak}$.

Both Lemma 1 and Lemma 2 show that, for a given Southern patent regime, the incentive for innovation by firm S is higher under export by firm N . Since exporting by the Northern firm involves a transportation cost, the equilibrium output of firm S is higher under exporting than under FDI by firm N , which, in turn, increases the Southern firm's gain from innovation under

exporting compared to FDI by firm N . This result is in line with the empirical evidence (Veugelers and Houte, 1990 and Goto and Odagiri, 2003), and poses an interesting question on whether inward FDI could always be conducive in fostering innovation in the host country.

Now we are in position to determine firm S 's incentive for innovation depending on the patent regime of the Southern country and the plant location decision of firm N .

Proposition 1: *We have $R_{FDI}^{weak} < R_{Export}^{weak} < R_{FDI}^{strong} < R_{Export}^{strong}$.*

Proof: See Appendix A for the proof.

Proposition 1 shows that the Southern firm has lower incentive for innovation under weak patent protection than under strong patent protection. There are two ways that a strong patent protection helps to increase firm S 's incentive for innovation. On one hand, a strong Southern patent regime increases the profit of firm S under innovation by protecting its product from knowledge spillover. This is similar to the usual R&D inducing effect of a strong patent protection. On the other hand, a strong Southern patent regime reduces the profit of firm S under no innovation by eliminating knowledge spillover, thus increasing the gain of firm S from innovation.

4. Export or FDI?

Now determine the equilibrium plant location decision of firm N . Firm N prefers FDI to export if $\Pi_N^F > \Pi_N^E$. However, previous section shows that whether firm S innovates or not may depend on firm N 's decision on export and FDI. Hence, firm N 's plant location decision should internalize

the R&D decision of firm S while deciding whether to undertake FDI or to export. As a result, we consider the following cases.

- (i) $R_{Export}^{strong} < R$, which implies that firm S does not innovate irrespective of the plant location decision of firm N and the patent regime in the South. This is similar to the previous works where firm S does not innovate. This case creates the benchmark for our analysis.
- (ii) $R < R_{FDI}^{weak}$, which is in contrast to case (i) and considers another extreme situation where S innovates irrespective of the plant location decision of firm N and the patent regime in the South.
- (iii) $R_{FDI}^{weak} < R < R_{Export}^{weak}$, which implies that firm S does not innovate if the Southern patent protection is weak and firm N undertakes FDI.
- (iv) $R_{Export}^{weak} < R < R_{FDI}^{strong}$, which implies that firm S innovates only under a strong Southern patent regime.
- (v) $R_{FDI}^{strong} < R < R_{Export}^{strong}$, which implies that firm S innovates under a strong Southern patent regime provided firm N exports.

4.1. If $R_{Export}^{strong} < R$

First, consider the case where the R&D cost of firm S is so high that it does not innovate irrespective of the Southern patent regime and the plant location decision of firm N . This case corresponds to the previous works where the Southern firm can only imitate the product of the Northern firm, thus creating the benchmark for our analysis.

Proposition 2: *If the cost of innovation is such that $R_{Export}^{strong} < R$, firm N 's incentive for FDI is higher under strong patent protection in the South for all feasible values of t and γ .*

Proof: See Appendix B for the proof.

The above result is due to the standard argument for a strong patent protection in the South. If firm S never innovates, strong patent protection helps to protect the product of firm N , thus creating higher incentive for FDI under strong patent protection.

4.2. If $R < R_{FDI}^{weak}$

In contrast to the previous subsection, where firm S never innovates, we now consider the other extreme case where the R&D cost of firm S is so small that it innovates irrespective of the Southern patent regime and the mode of production of firm N .

Proposition 3: *If the cost of innovation is small enough (i.e., $R < R_{FDI}^{weak}$), firm N 's incentive for*

FDI is higher under strong patent protection in the South if $t > \hat{t} \equiv a(2 - \gamma) \frac{6\gamma + 2\gamma^2 + 7}{23 + 14\gamma - 2\gamma^2 - 2\gamma^3}$

and $\gamma > \hat{\gamma} \approx 0.753$. Otherwise, firm N 's incentive for FDI is higher under weak patent protection in the South.

Proof: See Appendix C for the proof.

The reason for the difference in Proposition 2 and Proposition 3 is as follows. On one hand, innovation by the Southern firm reduces the Northern firm's profit under a stronger Southern patent system by creating product-market competition. On the other hand, innovation

by the Southern firm increases the Northern firm's profit under a weaker Southern patent system by increasing its product range due to knowledge spillover. Although these effects are true under both exporting and FDI by the Northern firm, we find that, on the balance, whether innovation by the Southern firm (compared with no innovation by the Southern firm) reduces the incentive for FDI under a stronger Southern patent system depends on the degree of product differentiation and transportation cost.

The FDI incentive of firm N is higher under a weak Southern patent system if either product differentiation is sufficiently large (i.e., γ is sufficiently small) or the transportation cost is sufficiently small (i.e., t is sufficiently small). For any $\gamma \in [0,1)$, the profit of firm N is higher under a strong Southern patent regime compared with a weak Southern patent regime, irrespective of exporting and FDI by firm N . Further, while the profit under FDI is independent of t , the profit of firm N under export reduces with t for two reasons. First, given the outputs, a higher t reduces the per unit profit of firm N . Second, given the per unit profit of firm N , a higher t reduces its output and profit.

If $t \rightarrow 0$, the output of firm N is *almost* the same under exporting and FDI, for both weak and strong patent regimes. In this situation, the output effect of a higher t is the important factor, and the loss of market share under export due to a rise in t is more under the weak patent regime compared with the strong patent regime. As a result, if $t \rightarrow 0$, firm N 's relative benefit from FDI over export is higher under weak patent protection compared with strong patent protection, thus creating higher incentive for FDI under weak patent protection for $\gamma \in [0,1)$ and $t \rightarrow 0$.

If $t = \frac{a}{2}$, the output and profit of firm N under export tend to zero if there is a weak Southern patent regime, while they are positive under a strong Southern patent regime, for any

$\gamma \in [0,1)$. In this situation, the profit gain of firm N under export due to a lower t is negligible under weak patent protection, while it is significant under strong patent protection. However, if $\gamma \rightarrow 0$, firm N 's gain in profit due to the strong patent protection is higher under export than under FDI. While negligible competition due to a large product differentiation increases, firm N 's profit significantly under strong patent protection for both FDI and exporting, it only increases firm N 's profit under FDI significantly for weak patent protection. As a result, firm N 's profit difference between FDI and exporting is higher under weak patent protection than under strong patent protection. If $\gamma \rightarrow 1$, competition between the products are severe and the profits of firm N are very much similar under weak and strong patent regimes, for both FDI and exporting. However, in this situation, firm N 's profit difference between FDI and exporting is higher under strong patent protection than under weak patent protection.

4.3. If $R_{\text{FDI}}^{\text{weak}} < R < R_{\text{Export}}^{\text{weak}}$

Now consider the case where the R&D cost of firm S is such that it does not innovate under the weak Southern patent regime if firm N undertakes FDI but innovates otherwise.

Proposition 4: *If the cost of innovation is such that $R_{\text{FDI}}^{\text{weak}} < R < R_{\text{Export}}^{\text{weak}}$, firm N 's incentive for FDI is higher under strong patent protection in the South.*

Proof: See Appendix D for the proof.

The intuition for the above result is as follows. Consider that the Southern patent protection is weak. If the cost of innovation is such that firm S does not innovate under FDI by firm N , the profit of firm N under FDI reduces compared to the situation where firm S innovates

under FDI by firm N . This is because, in the latter situation, firm N gets the opportunity to produce the product of firm S , while no innovation by firm S eliminates that possibility. As a result, if firm S does not innovate when firm N undertakes FDI and there is a weak Southern patent regime, strong patent protection in the South always increases firm N 's incentive for FDI.

4.4. If $R_{\text{Export}}^{\text{weak}} < R < R_{\text{FDI}}^{\text{strong}}$

Now consider the situation where the R&D cost of firm S is such that it innovates only under strong Southern patent regime, irrespective of exporting or FDI by firm N .

Proposition 5: *If the cost of innovation is such that $R_{\text{Export}}^{\text{weak}} < R < R_{\text{FDI}}^{\text{strong}}$, firm N 's incentive for FDI*

is higher under strong patent protection in the South if either $\gamma < \frac{\sqrt{13}-3}{2}$ or $\gamma > \frac{\sqrt{13}-3}{2}$ and

$$t > \tilde{t} \equiv a \frac{(2-\gamma)(3\gamma+\gamma^2-1)}{(\gamma+1)(7-\gamma^2)}.$$

Proof: See Appendix E for the proof.

Proposition 5 can be explained as follows. Strong patent protection in the South eliminates knowledge spillover but encourages innovation by the Southern firm. Hence, the strong patent protection helps to increase the profit of firm N under both export and FDI, since the product differentiation is higher under Southern innovation than under knowledge spillover. If the products are sufficiently differentiated, the profit gain for firm N under strong patent protection (compared with weak patent protection) is higher under FDI compared to exporting, since the trade cost creates the distortion under exporting. However, if the products are not very much differentiated, firm N 's profit gain under strong patent protection is higher under FDI

compared to exporting provided exporting creates significant distortion, which happens for sufficiently high transportation cost. Therefore, if the products are not very differentiated and the transportation cost is sufficiently small, firm N 's profit gain under strong patent protection is higher under exporting compared to FDI, thus creating higher FDI incentive under weak patent protection in this situation.

4.5. If $R_{\text{FDI}}^{\text{strong}} < R < R_{\text{Export}}^{\text{strong}}$

Finally, we consider the case where the R&D cost of firm S is such that it innovates only if firm N exports and there is strong patent protection in the South.

Proposition 6: *If the cost of innovation is such that $R_{\text{FDI}}^{\text{strong}} < R < R_{\text{Export}}^{\text{strong}}$, firm N 's incentive for FDI is higher under strong patent protection in the South for all feasible values of t and γ .*

Proof: See Appendix F for the proof.

Intuitively, the above result can be explained as follows. As usual, strong patent protection helps to protect the product of firm N , which creates an incentive for FDI. Moreover, since firm S innovates only if there is strong patent protection and firm N exports, FDI by firm N under strong patent protection eliminates product market competition by deterring Southern innovation, thus encouraging firm N to undertake FDI under strong patent protection.

The following table summarizes above findings.

R	F^{strong} - F^{weak} > 0 for
$R_{\text{Export}}^{\text{strong}} < R$	$t > 0, \gamma > 0$
$R_{\text{FDI}}^{\text{strong}} < R < R_{\text{Export}}^{\text{strong}}$	$t > 0, \gamma > 0$
$R_{\text{Export}}^{\text{weak}} < R < R_{\text{FDI}}^{\text{strong}}$	$\gamma < \frac{\sqrt{13}-3}{2}$ or $\gamma > \frac{\sqrt{13}-3}{2}$ and $t > \tilde{t} \equiv a \frac{(2-\gamma)(3\gamma+\gamma^2-1)}{(\gamma+1)(7-\gamma^2)}$
$R_{\text{FDI}}^{\text{weak}} < R < R_{\text{Export}}^{\text{weak}}$	$t > 0, \gamma > 0$
$R < R_{\text{FDI}}^{\text{weak}}$	$t > \hat{t} \equiv a(2-\gamma) \frac{6\gamma+2\gamma^2+7}{23+14\gamma-2\gamma^2-2\gamma^3}$ and $\gamma > \hat{\gamma} \approx 0.753$

6. Conclusion

Though evidence suggests considerable innovative activities by the Southern firms, the literature on patent protection did not pay attention to these activities in determining the effects of Southern patent regime on inward FDI. We take up this issue here. In a model of international oligopoly, we show that the effect of Southern patent regime on FDI by the Northern firm depends on the Southern firm's innovative capability, the degree of product differentiation and transportation cost. If either the cost of Southern innovation is sufficiently low such that the Southern firm innovates irrespective of the Southern patent regime or the Southern firm's cost of innovation is moderate such that it innovates only under a strong Southern patent regime, a stronger Southern patent regime may reduce the Northern firm's incentive for FDI. For all other costs of Southern innovation, a stronger Southern patent regime increases the Northern firm's incentive for FDI.

An important policy implication resulting from our paper is that Southern countries may need to consider the trade off between attracting FDI and encouraging domestic innovation while designing their patent policies. There are situations where a strong patent protection increases domestic innovation, yet deters FDI.

While our framework of an international duopoly helps us to present a simplified analysis keeping the central points in focus, the implications of more firms are easy to see. If there are multiple firms in the South, given the other specifications of the model, the market will be more competitive. If the cost of innovation is very low so that all Southern firms innovate, the Northern firm may have higher FDI incentive under a weak Southern patent regime, since it could have more profits by imitating the Southern goods and also avoiding the transportation cost. However, when the cost of innovation increases, which reduces the possibility of new product development in the South, the incentive for FDI by the Northern firm under stronger Southern patent regime increases, since it helps to protect the product of the Northern firm.

It is important to note that we have considered the incentive for inward FDI by the Northern firm. However, in the present economic scenario where the Southern firms are increasingly prominent in international trade and capital flows, it may also important to identify the effects of the patent regimes on two-way FDIs where the Southern firms can also undertake FDI. In this respect, it would be interesting to see the implications of Northern demand and also to focus on patent harmonization. We intend to take up these issues in our future research.

Appendix

A Proof of Proposition 1

We get from (39) and (38) that $\frac{\partial(R_{FDI}^{strong} - R_{Export}^{weak})}{\partial t} = -\frac{2(1-\gamma)(a+t)}{9(1+\gamma)} < 0$. Hence, $R_{FDI}^{strong} - R_{Export}^{weak}$

reaches minimum at $t = \frac{a}{2}$, and the minimum value of $R_{FDI}^{strong} - R_{Export}^{weak} = \frac{1}{4}a^2\gamma \frac{3\gamma + \gamma^2 + 4}{(\gamma+1)(\gamma+2)^2} > 0$,

which proves that $R_{FDI}^{strong} > R_{Export}^{weak}$.

Comparing R_{FDI}^{strong} and R_{Export}^{strong} from (39) and (40), we get

that $R_{Export}^{strong} - R_{FDI}^{strong} = \frac{t\gamma}{(2+\gamma)(2-\gamma)} > 0$, which proves that $R_{Export}^{strong} > R_{FDI}^{strong}$.

Comparing R_{FDI}^{weak} and R_{Export}^{weak} from (37) and (38), we get

that $R_{Export}^{weak} - R_{FDI}^{weak} = \frac{t(1-\gamma)(2a+t)}{9(1+\gamma)} > 0$, which proves that $R_{Export}^{weak} > R_{FDI}^{weak}$.

Taken together, we get that $R_{FDI}^{Process} < R_{Export}^{Process} < R_{FDI}^{Product} < R_{Export}^{Product}$. ■

B Proof of Proposition 2

Consider $R_{Export}^{strong} < R$. Under a weak Southern patent protection, it follows from (9) and (12) that

firm N prefers FDI to exporting for $F < F_1^{weak(NI)} = \frac{a^2}{9} - \frac{(a-2t)^2}{9}$.

However, under a strong Southern patent protection, it follows from (3) and (6) that firm

N prefers FDI to exporting for $F < F_2^{strong(NI)} \equiv \left(\frac{a}{2}\right)^2 - \left(\frac{a-t}{2}\right)^2$.

We get that $F_2^{strong(NI)} > F_1^{weak(NI)}$, which proves the result. ■

C Proof of Proposition 3

Consider $R < R_{FDI}^{weak}$. Under a weak Southern patent protection, it follows from (10) and (13) that

$$\text{firm } N \text{ prefers FDI to exporting for } F < F_3^{weak(1)} \equiv \frac{2a^2}{9(1+\gamma)} - \frac{2(a-2t)^2}{9(1+\gamma)}.$$

However, if the Southern patent regime is strong, it follows from (4) and (7) that firm N

$$\text{prefers FDI to exporting for } F < F_4^{strong(1)} \equiv \left(\frac{a}{2+\gamma}\right)^2 - \left(\frac{a(2-\gamma)-2t}{4-\gamma^2}\right)^2.$$

We get that $F_4^{strong(1)} > F_3^{weak(1)}$ if $t > \hat{t} \equiv a(2-\gamma) \frac{6\gamma+2\gamma^2+7}{23+14\gamma-2\gamma^2-2\gamma^3}$. However,

$\hat{t} < t_{\max} = \frac{a}{2}$ if $\gamma > \hat{\gamma} \approx 0.753$. Therefore, firm N 's incentive for FDI is higher under strong patent

protection in the South if $t > \hat{t}$ and $\gamma > 0.753$. Otherwise, firm N 's incentive for FDI is higher under weak patent protection in the South. ■

D Proof of Proposition 4

Consider $R_{FDI}^{weak} < R < R_{Export}^{weak}$. Under a weak Southern patent protection, it follows from (10) and

$$(12) \text{ that firm } N \text{ prefers FDI to exporting for } F < F_5^{weak(NI)} \equiv \left(\frac{a}{3}\right)^2 - \frac{2(a-2t)^2}{9(1+\gamma)}.$$

However, under a strong Southern patent regime, it follows from (4) and (7) that firm N

$$\text{prefers FDI to exporting for } F < F_4^{strong(1)} \equiv \left(\frac{a}{2+\gamma}\right)^2 - \left(\frac{a(2-\gamma)-2t}{4-\gamma^2}\right)^2.$$

Setting $F_4^{strong(I)} = F_5^{weak(NI)}$, we get the following two roots of t :

$$\frac{a(14+5\gamma-2\gamma^2-2\gamma^3-(-2+\gamma)\sqrt{-43-64\gamma-7\gamma^2+26\gamma^3+14\gamma^4+2\gamma^5})}{2(23+14\gamma-2\gamma^2-2\gamma^3)}$$

$$\frac{a(14a+5\gamma-2\gamma^2-2\gamma^3+(-2+\gamma)\sqrt{-43-64\gamma-7\gamma^2+26\gamma^3+14\gamma^4+2\gamma^5})}{2(23+14\gamma-2\gamma^2-2\gamma^3)}.$$

Since $-43-64\gamma-7\gamma^2+26\gamma^3+14\gamma^4+2\gamma^5 < 0$ for $\gamma \in [0,1]$, neither of these roots is real, irrespective of the value of γ . Hence, there is no real value of t such that $F_4^{strong(I)} = F_5^{weak(NI)}$.

Let us now take a value of γ , say $\gamma=0$. We get that $F_4^{strong(I)} > F_5^{weak(NI)}$ if $\gamma=0$. Hence, for any a , t and γ , we get $F_4^{strong(I)} > F_5^{weak(NI)}$, which implies that firm N 's incentive for FDI is higher under strong patent protection. ■

E Proof of Proposition 5

Consider $R_{Export}^{weak} < R < R_{FDI}^{strong}$. Under a weak Southern patent regime, it follows from (4) and (9)

$$\text{that firm } N \text{ prefers FDI to exporting for } F < F_1^{weak(NI)} = \frac{a^2}{9} - \frac{(a-2t)^2}{9}.$$

However, under a strong Southern patent regime, it follows from (4) and (7) that firm N

$$\text{prefers FDI to exporting for } F < F_4^{strong(I)} \equiv \left(\frac{a}{2+\gamma}\right)^2 - \left(\frac{a(2-\gamma)-2t}{4-\gamma^2}\right)^2.$$

We get that

$$F_4^{strong(I)} - F_1^{weak(NI)} = \frac{a^2}{(2+\gamma)^2} - \frac{(a(2-\gamma)-2t)^2}{(4-\gamma^2)^2} - \frac{a^2}{9} + \frac{(a-2t)^2}{9} > 0$$

if $t > \tilde{t} \equiv a \frac{(2-\gamma)(3\gamma+\gamma^2-1)}{(\gamma+1)(7-\gamma^2)}$, where $\tilde{t} < t_{\max} = \frac{a}{2}$. However, $\tilde{t} > 0$ provided $\gamma > \frac{\sqrt{13}-3}{2}$.

Therefore, firm N 's incentive for FDI is higher under strong patent protection if either

$\gamma < \frac{\sqrt{13}-3}{2}$ so that $t > 0$ is always greater than \tilde{t} , or $\gamma > \frac{\sqrt{13}-3}{2}$ and $t > \tilde{t}$. ■

F Proof of Proposition 6

Consider $R_{\text{FDI}}^{\text{strong}} < R < R_{\text{Export}}^{\text{strong}}$. Under a weak Southern patent regime, it follows from (9) and (12)

that firm N prefers FDI to exporting for $F < F_1^{\text{weak(NI)}} = \frac{a^2}{9} - \frac{(a-2t)^2}{9}$.

However, under a strong Southern patent regime, it follows from (4) and (6) that firm N

prefers FDI to exporting for $F < F_6^{\text{strong(NI)}} \equiv \left(\frac{a}{2}\right)^2 - \left(\frac{a(2-\gamma)-2t}{4-\gamma^2}\right)^2$.

We get that $F_6^{\text{strong(NI)}} > F_2^{\text{strong(NI)}}$ as $\left(\frac{a-t}{2}\right)^2 - \left(\frac{a(2-\gamma)-2t}{4-\gamma^2}\right)^2 \geq 0$ for $\gamma \in [0,1)$.

Further, we get that $F_2^{\text{strong(NI)}} > F_1^{\text{weak(NI)}}$. Thus, it proves that $F_6^{\text{strong(NI)}} > F_1^{\text{weak(NI)}}$. ■

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