

# Intellectual Property Rights Protection, FDI, and Process Innovation in North-South Trade\*

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## Abstract

I examine the intellectual property rights (IPR) protection in the South when it affects technological spillovers. A Northern firm, which conducts cost-reducing R&D, chooses exporting or FDI to serve the Southern market. Spillovers occur under FDI. It turns out that there is a non-monotonic relationship between the optimal IPR protection and efficiency of R&D. With low R&D efficiency, the South chooses a stringent protection to induce FDI or an even more stringent protection to encourage a higher R&D investment. A stringent protection is also chosen with high efficiency. With medium efficiency, however, a lax protection is chosen to induce exporting.

*Keywords:* Intellectual property rights; foreign direct investment; technological spillovers; process R&D; North-South trade.

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# 1 Introduction

Many developing countries try to attract foreign direct investment (FDI) from developed countries. One of the main motives for them to attract FDI is to obtain advanced technology from multinational enterprises (MNEs). For firms in developing countries that have insufficient capability to engage in research and development (R&D) activities by themselves, it is important to obtain advanced technology from MNEs that extensively conduct R&D. Although technology transfers to subsidiaries of MNEs and joint ventures between local firms and MNEs are major sources of advanced technology for developing countries, technological spillovers are also important.<sup>1</sup>

The channels through which technological spillovers occur have been well documented (Mansfield *et al.*, 1981; Mansfield, 1985; Neven and Siotis, 1996). They include common suppliers of inputs and customers, turnover of employees, and informal communication networks among engineers and scientists. Technological spillovers through FDI are empirically confirmed by a number of studies (Branstetter, 2005; Haskel *et al.*, 2002; Javorcik, 2004; Keller and Yeaple, 2003; Kiyota, 2006; Takii, 2005), while some studies do not find significant spillovers (Aitken and Harrison, 1999; Haddad and Harrison, 1993).<sup>2</sup> Among these studies, Keller and Yeaple (2003) find that there are stronger technological spillovers to U.S. manufacturing firms from FDI than from imports. Moreover, the analyses by Javorcik (2004) and Takii (2005) suggest that even developing countries benefit

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<sup>1</sup>Technological spillover is distinguished from technology transfer in the sense that the former is unintended by the source of the knowledge. It is also distinguished from imitation in the sense that the former does not necessarily require costly activities by those who obtain knowledge.

<sup>2</sup>See Keller (2004) for a survey of this issue.

from spillovers through inward FDI.

Some researchers argue that technological spillovers are greatly affected by a country's level of intellectual property rights (IPR) protection. Countries that implement lax IPR protection policies would benefit from spillovers to a large extent. However, this relationship is not so obvious once the effects of IPR policy on MNEs' location choices and on their incentives to choose the extent of R&D activities are taken into account. Firms in developing countries would benefit from MNEs' R&D to a larger extent when MNEs produce locally in developing countries than when they produce in their own or third countries and export goods to developing countries. Although a lax IPR protection policy would give rise to a high degree of spillovers, it may deter MNEs from investing in that country and may also reduce incentives for them to engage in R&D. Consequently, it is not obvious whether developing countries seeking to reap benefits from spillovers would adopt a lax or stringent IPR protection policy.

As is well known, one important product of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) was the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS Agreement) in 1994. This agreement requires all members, including both developed and developing countries, to adopt a set of universal minimum standards on IPR protection. However, countries like China, for example, have been criticized for their insufficient enforcement of IPR protection (USTR, 2005).<sup>3</sup>

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<sup>3</sup>The United States Trade Representative (USTR) publishes annually its review of foreign countries' IPR practices. USTR (2005) identifies 52 countries or economies with IPR-related problems. Fourteen of them, including Argentina, Brazil, China, India, Indonesia, Pakistan, the Philippines, and Russia, fall into the "priority watch list," which means that IPR infringement in those countries merits close attention.

Thus, even under the TRIPS Agreement, developing countries may have an incentive to manipulate their IPR policy to facilitate technological spillovers from MNEs.

The main purpose of this paper is to examine developing countries' IPR policy when it affects technological spillovers through FDI. While IPR policy covers both patents and know-how, the analysis in this paper would be more relevant to the latter because this paper deals with cost-reducing R&D. In order to address this issue, I construct a simple North-South trade model in which a Northern firm and a Southern firm compete in the Southern market. The Northern firm can choose either to export to the Southern market or to undertake FDI in the South. Initially, these two firms have access to the same technology. The Northern firm can conduct cost-reducing R&D, or *process innovation*. The Northern firm may be very efficient in its R&D, which means that marginal cost of production is greatly reduced by a small investment in R&D, or may be less efficient in its R&D, which means that only a small cost reduction is attained even by a relatively large investment in R&D. In the model, the efficiency of the Northern firm's R&D is captured by a parameter. As long as the Northern firm produces in its own country, knowledge does not leak out to the Southern firm. However, if the Northern firm invests in the South, spillovers of knowledge occur, benefiting the Southern firm from the Northern firm's R&D. The degree of spillover depends on the Southern IPR protection policy. If the Southern IPR protection policy is stringent, spillovers are low. If it is lax, on the other hand, spillovers are high. Since the Southern government also imposes tariffs on imports, the Northern firm faces a trade-off between protecting its knowledge by keeping

its plant in the North and avoiding tariffs by undertaking FDI.<sup>4</sup> The market structure in the South is endogenously determined. Even when the Northern firm exports to the Southern market, the market structure may be duopoly, if efficiency of R&D is low or if tariff protection is high enough. The Southern government may manipulate its IPR policy to attract FDI or to induce the foreign firm to export.

The main results are as follows. First, when the efficiency of R&D is low, the Southern government may choose a stringent IPR policy to induce the Northern firm to undertake FDI or an even more stringent IPR policy to stimulate the Northern firm's incentive to engage in a higher level of R&D. In these cases, the Southern firm benefits from spillovers. Second, when the efficiency of R&D is medium, the South sets a lax IPR policy to induce the Northern firm to export. In exporting, the Northern firm becomes a monopolist because of a large technology gap between the two firms. Third, with high R&D efficiency, the South sets a stringent IPR policy to allow monopoly by the Northern firm under FDI. In this way, I find a non-monotonic relationship between the optimal Southern IPR policy and efficiency of R&D.

In the literature, a large number of studies have investigated the effects of IPR policy through spillovers of *product innovation*, which is aimed at developing new products or improving the quality of existing products, in the framework of North-South trade (Deardorf, 1992; Helpman, 1993; Taylor, 1994; Lai, 1998; Glass and Saggi, 2002; Lai and Qiu, 2003; Qiu and Lai, 2004). However, there are only a small number of studies on IPR policy related to spillovers of *process innovation* (Chin and Grossman, 1990; Taylor,

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<sup>4</sup>In this sense, the model in this paper has some features in common with models in the literature on tariff-jumping FDI under oligopoly (e.g., Smith, 1987; Motta, 1992).

1993; Žigić, 1998, 2000; Naghavi, 2006).<sup>5</sup> This is rather surprising because theoretical studies on spillovers of innovation have mainly focused on process innovation (Katz, 1986; d’Aspremont and Jacquemin, 1988; Kamien *et al.* 1992; Suzumura, 1992).

Chin and Grossman (1990) and Žigić (1998, 2000) explore the effects of the Southern IPR policy on the Northern firm’s R&D and welfare in each country. These papers focus on international spillovers of knowledge and do not consider the possibility of FDI. Taylor (1993) examines the effects of Southern IPR protection when the Northern firm endogenously chooses “masking” product technology and the Southern firm engages in reverse engineering. In his analysis, while the Southern firm’s production cost falls due to its reverse engineering, the Northern firm does not directly conduct process innovation.

Naghavi (2006) is the most similar to my paper. Like my paper, he examines the Southern country’s incentives to use its IPR policy to manipulate the Northern firm’s decisions on R&D and plant location. Unlike my paper, however, he assumes the Northern firm can monopolize the Southern market by exporting. This simple difference makes the results in the two papers quite different. In his study, the Southern government always tries to attract FDI by choosing a stringent IPR policy, and the optimal IPR policy is characterized by corner solutions. In my paper, these results do not necessarily hold.

The rest of the paper proceeds as follows. Section 2 sets up the model. Section 3 analyzes the Northern firm’s choice of exporting or FDI. Section 4 examines the optimal IPR policy. Section 5 discusses the optimal policy when the South sets IPR and tariff policy before the Northern firm’s decision on FDI. Section 6 concludes.

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<sup>5</sup>Diwan and Rodrik (1991) consider a general model that fits both product and process innovation. They assume a continuum of potential technologies, with a different distribution of preferences for these in the North and the South.

## 2 The Model

There are two countries, the “North” and the “South.” In each country, there is only one firm. I call them “firm N” and “firm S” respectively. These firms produce a homogeneous good. The markets in the two countries are segmented. I focus on the Southern market. The inverse demand in the Southern market is given by  $p(y_n + y_s) = a - (y_n + y_s)$ , where  $a > 0$  is a parameter for measuring the market size and  $y_n$  and  $y_s$  are outputs of firms N and S, respectively. The firms compete in quantities in Cournot fashion.

Initially, these two firms have access to the same “old” technology, which is expressed by a constant marginal cost,  $c$ . I assume that  $c < a$  holds. However, firm N is capable of conducting process innovation, or cost-reducing R&D. Following Chin and Grossman (1990), I assume that by investing  $x$  in the process innovation, firm N’s marginal cost is reduced by  $f(x) = (\gamma x)^{1/2}$ , where  $\gamma > 0$  is a parameter for measuring the efficiency of the process innovation. The choice of  $x$  is restricted to the range of  $x < c^2/\gamma$ .

Firm N decides whether to produce goods in the North and export them to the South, or to invest in the South and produce goods locally. When it exports, it faces a specific tariff  $t \geq 0$ . When it undertakes FDI, technological spillovers occur. The degree of spillovers depends on the Southern IPR policy. I assume that the degree of technological spillovers is inversely proportional to the stringency of the Southern IPR policy. For simplicity, I assume that both the degree of spillovers and the stringency of the Southern IPR policy are captured by a single parameter.<sup>6</sup> Then, the level of Southern

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<sup>6</sup>In principle, two different parameters should be used for the degree of technological spillovers and the stringency of IPR policy. However, using a single parameter for them makes the model tractable. Actually, such a treatment is quite popular in the literature. See, for example, Chin and Grossman (1990), Žigić (1998, 2000), and Naghavi (2006).

IPR protection, or the degree of technological spillovers, is measured by  $s \in [0, 1]$ .  $s = 0$  corresponds to full protection, which means no spillovers, and  $s = 1$  corresponds to no protection, which means perfect spillovers.

The profits of firms N and S are respectively given by

$$\pi_n(y_n, y_s, x) = \begin{cases} \{p(y_n + y_s) - t - (c - f(x))\} y_n - x, & \text{if firm N exports,} \\ \{p(y_n + y_s) - (c - f(x))\} y_n - x, & \text{if firm N undertakes FDI,} \end{cases}$$

$$\pi_s(y_n, y_s, x) = \begin{cases} \{p(y_n + y_s) - c\} y_s, & \text{if firm N exports,} \\ \{p(y_n + y_s) - (c - sf(x))\} y_s, & \text{if firm N undertakes FDI.} \end{cases}$$

The Southern government chooses a tariff  $t \geq 0$  and the IPR protection level  $s \in [0, 1]$  to maximize welfare in the South, which is given by

$$W(t, s) = \begin{cases} \pi_s(t) + CS(t) + ty_n, & \text{if firm N exports,} \\ \pi_s(s) + CS(s), & \text{if firm N undertakes FDI,} \end{cases}$$

where  $CS$  is consumer surplus in the South, which is given by  $CS = (y_n + y_s)^2/2$ . Since the main focus of this paper is the IPR policy, I assume that the Southern government chooses its IPR policy before firm N decides whether to undertake FDI, whereas it chooses a tariff after firm N decides to export to the South.<sup>7</sup> This assumption prevents the Southern government from imposing an excessive tariff strategically to induce firm N to undertake FDI, coupled with a lax IPR policy. The timing of the policy decision is also based on the fact that the IPR policy involves a longer period of legislative procedure.

The tariff policy is, in contrast, relatively flexible, because policy instruments under the

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<sup>7</sup>Naghavi (2006) considers the same game structure. In Section 5, I briefly discuss the case in which the Southern government chooses both the IPR policy and the tariff before firm N decides whether to undertake FDI.

GATT/WTO rule, including antidumping measures and countervailing duties, can be implemented within a relatively short period.

The timing of the game is as follows: In stage 1, the Southern government chooses  $s$  to maximize domestic welfare; In stage 2, firm N decides whether to export or invest; In stage 3, the Southern government chooses  $t$  if firm N exports;<sup>8</sup> In stage 4, firm N chooses the level of process R&D; In stage 5, firms compete in Cournot fashion. The solution concept is the subgame perfect Nash equilibrium (SPNE).

### **3 Market Structure and the Endogenous Mode of Supply**

In this section, I first analyze the market structure in cases where firm N exports and where it undertakes FDI. Then, I investigate firm N's decision on the mode of supply.

#### **3.1 Stages 3, 4, and 5 in the subgame in which firm N exports**

When firm N chooses to export to the Southern market, there are three possible market structures: (i) duopoly; (ii) monopoly by firm N (which I call "foreign monopoly"); and (iii) domestic monopoly. I look at these three cases in order.

##### **3.1.1 The case of duopoly**

When duopoly is a viable market structure, each firm chooses its quantity to maximize its own profits at the final stage, given the duopolistic market structure, tariff level, and its rival's output level. The first-order conditions (FOCs) are given by  $\partial\pi_n/\partial y_n = 0$  and

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<sup>8</sup>In section 5, the Southern government chooses both  $s$  and  $t$  in stage 1.

$\partial\pi_s/\partial y_s = 0$ . Each firm's outputs and profits are respectively given by

$$y_n^{Ed} = \frac{a - c - 2t + 2(\gamma x)^{1/2}}{3}, \quad \pi_n^{Ed} = \frac{(a - c - 2t + 2(\gamma x)^{1/2})^2}{9} - x, \quad (1)$$

$$y_s^{Ed} = \frac{a - c + t - (\gamma x)^{1/2}}{3}, \quad \text{and} \quad \pi_s^{Ed} = \frac{(a - c + t - (\gamma x)^{1/2})^2}{9}, \quad (2)$$

where the superscript “*Ed*” indicates variables under exporting with duopoly.

In stage 4, firm N chooses  $x$  to maximize  $\pi_n^{Ed}$ . The optimal level of R&D is given by

$$x^{Ed} = \frac{4\gamma(a - c - 2t)^2}{(9 - 4\gamma)^2}. \quad (3)$$

Substitute (3) into (1) to obtain

$$y_n^{Ed} = \frac{3(a - c - 2t)}{9 - 4\gamma} \quad \text{and} \quad \pi_n^{Ed} = \frac{(a - c - 2t)^2}{9 - 4\gamma}. \quad (4)$$

In order for the duopolistic market structure to emerge,  $t \leq (a - c)/2$  must hold.

### 3.1.2 The case of foreign monopoly

Firm N can attain a monopoly position in the Southern market by choosing a high level of R&D that makes it unprofitable for firm S to produce goods, if it is optimal for firm N to do so. From  $y_s^{Ed} = 0$ , use (2) to obtain

$$x^{Em} = \frac{(a - c + t)^2}{\gamma}, \quad (5)$$

where the superscript “*Em*” denotes variables under exporting with foreign monopoly.

Firm N's output and profits are respectively given by

$$y_n^{Em} = \frac{a - c - t + (\gamma x)^{1/2}}{2} = a - c \quad \text{and} \quad \pi_n^{Em} = (a - c)^2 - \frac{(a - c + t)^2}{\gamma}. \quad (6)$$

As seen in (6),  $y_n^{Em}$  is independent of  $t$  and  $\gamma$ . This property partly comes from the linearity of the demand but is robust for general  $f(x)$ . In order for this case to occur,  $t \leq (\gamma^{1/2} - 1)(a - c)$  must hold. For  $\gamma \leq 9/4$ ,  $(\gamma^{1/2} - 1)(a - c) \leq (a - c)/2$  holds.

### 3.1.3 The case of domestic monopoly under prohibitive tariff

If the Southern government imposes a prohibitive tariff, which is  $t > (a - c)/2$ , firm S becomes the monopolist in the Southern market. Since this is the standard monopoly case, firm S's output and profits are respectively given by  $y_s^{Ep} = (a - c)/2$  and  $\pi_s^{Ep} = (a - c)^2/4$ , where the superscript "Ep" denotes variables under exporting with a prohibitive tariff. Consumer surplus is given by  $CS^{Ep} = (a - c)^2/8$  and Southern welfare is given by

$$W^{Ep} = CS^{Ep} + \pi_s^{Ep} = \frac{3(a - c)^2}{8}. \quad (7)$$

### 3.1.4 The optimal tariff

In stage 3, the Southern government chooses  $t$  to maximize domestic welfare in the South.

Firm S's output under duopoly is obtained by substituting (3) into (2):

$$y_s^{Ed} = \frac{(3 - 2\gamma)(a - c) + 3t}{9 - 4\gamma}. \quad (8)$$

Thus,  $y_s^{Ed} \geq 0$  holds for all  $t \geq 0$  when  $\gamma \leq 3/2$ . Southern welfare under duopoly is

$$W^{Ed}(t) = \frac{((3 - 2\gamma)(a - c) + 3t)^2}{(9 - 4\gamma)^2} + \frac{(2(3 - \gamma)(a - c) - 3t)^2}{2(9 - 4\gamma)^2} + \frac{3t(a - c - 2t)}{9 - 4\gamma}. \quad (9)$$

The tariff that maximizes (9) for  $\gamma \leq 3/2$  is given by

$$t^* = \frac{3(3 - 2\gamma)(a - c)}{27 - 16\gamma}. \quad (10)$$

It holds that  $t^* \leq (a - c)/2$  for  $\gamma \leq 9/4$ . Substitute  $t^*$  into (9) to obtain

$$W^{Ed}(t^*) = \frac{3(7 - 4\gamma)(a - c)^2}{2(27 - 16\gamma)}. \quad (11)$$

For  $\gamma \in (3/2, 9/4)$ ,  $dW^{Ed}/dt < 0$  for  $t \geq 0$ . From (8),  $y_s^{Ed} > 0$  holds for  $t > \bar{t}$ , where

$$\bar{t} \equiv \frac{(2\gamma - 3)(a - c)}{3}. \quad (12)$$

Note that  $\bar{t} < (\gamma^{1/2} - 1)(a - c)$  holds.

Southern welfare in the case of foreign monopoly is given by

$$W^{Em}(t) = \frac{(a - c)^2}{2} + t(a - c). \quad (13)$$

Since  $dW^{Em}/dt = a - c > 0$ , the optimal tariff is the highest level that is consistent with this regime. From (4) and (6) it yields  $\pi_n^{Ed} - \pi_n^{Em} = \{3(a - c + t) - 2\gamma(a - c)\}^2 / (9 - 4\gamma)\gamma \geq 0$  for  $\gamma \leq 9/4$ , i.e., firm N prefers duopoly to foreign monopoly. Since duopoly emerges for  $t > \bar{t}$ , the highest tariff consistent with foreign monopoly is  $t = \bar{t}$ .

From (9) and (13), it is shown that  $W^{Ed}(t) \geq$  (resp.  $<$ )  $W^{Em}(t)$  holds for  $t \leq$  (resp.  $>$ )  $\bar{t}$ . The situation is depicted in figure 1. In the figure, the  $W^{Ed}$  curve and the  $W^{Em}$  curve are drawn. Since foreign monopoly prevails for  $t < \bar{t}$  and duopoly does for  $t > \bar{t}$ , the Southern welfare that is actually attained is given by the thick parts of the curves. The following lemma is then obtained.

**Lemma 1** *When firm N exports, (i) for  $\gamma \in (0, 3/2]$ , the Southern government imposes a tariff  $t^*$  and the market structure is duopoly; (ii) for  $\gamma \in (3/2, 9/4)$ , the Southern government imposes a tariff  $\bar{t}$  and the market structure is foreign monopoly.*

*Proof.* See the Appendix.

This proposition implies that once firm N decides to export to the Southern market, it is never optimal for the South to impose a prohibitive tariff.

### 3.2 Stages 4 and 5 in the subgame in which firm N undertakes FDI

I now turn to the case in which firm N undertakes FDI. When firm N undertakes FDI, duopoly or foreign monopoly emerges.

#### 3.2.1 The case of duopoly

As in the case of exporting, under duopoly FOCs yield each firm's outputs and profits:

$$y_n^{Fd} = \frac{a - c + (2 - s)(\gamma x)^{1/2}}{3}, \quad \pi_n^{Fd} = \frac{(a - c + (2 - s)(\gamma x)^{1/2})^2}{9} - x, \quad (14)$$

$$y_s^{Fd} = \frac{a - c - (1 - 2s)(\gamma x)^{1/2}}{3}, \quad \text{and} \quad \pi_s^{Fd} = \frac{(a - c - (1 - 2s)(\gamma x)^{1/2})^2}{9}, \quad (15)$$

where the superscript “ $Fd$ ” indicates variables under FDI with duopoly.

In stage 4, the optimal level of R&D is given by

$$x^{Fd} = \frac{\gamma(2 - s)^2(a - c)^2}{(9 - \gamma(2 - s)^2)^2}. \quad (16)$$

Substitute (16) into (14) to yield, respectively,

$$y_n^{Fd} = \frac{3(a - c)}{9 - \gamma(2 - s)^2} \quad \text{and} \quad \pi_n^{Fd} = \frac{(a - c)^2}{9 - \gamma(2 - s)^2}. \quad (17)$$

#### 3.2.2 The case of foreign monopoly

As in the case of exporting, firm N can attain a monopoly position by choosing a high level of R&D. From  $y_s^{Fd} = 0$ , use (15) to obtain

$$x^{Fm} = \frac{(a - c)^2}{\gamma(1 - 2s)^2}, \quad (18)$$

where the superscript “ $Fm$ ” denotes variables under FDI with foreign monopoly. Firm N’s output and profits are respectively given by

$$y_n^{Fm} = \frac{(1-s)(a-c)}{1-2s} \quad \text{and} \quad \pi_n^{Fm} = \frac{(\gamma(1-s)^2 - 1)(a-c)^2}{\gamma(1-2s)^2}. \quad (19)$$

### 3.3 Stage 2: Firm N’s choice of the mode of supply

In stage 2, firm N chooses whether to export to the South or undertake FDI, given the Southern IPR policy. Before analyzing firm N’s choice of the mode of supply, I examine which market structure emerges if firm N undertakes FDI.

#### 3.3.1 The market structure under FDI

When firm N undertakes FDI, from (17) and (19), it yields  $\pi_n^{Fd} - \pi_n^{Fm} = \{\gamma(2-s)(1-s) - 3\}^2(a-c)^2/\gamma(1-2s)^2(9-\gamma(2-s)^2) \geq 0$  for  $\gamma < 9/(2-s)^2$ . Thus, as in the case of exporting, firm N prefers duopoly to foreign monopoly.

Firm S’s output under duopoly is obtained by substituting (16) into (15)

$$y_s^{Fd} = \frac{(3-\gamma(2-s)(1-s))(a-c)}{9-\gamma(2-s)^2}. \quad (20)$$

Thus,  $y_s^{Fd} \geq 0$  for  $\gamma \leq 3/(2-s)(1-s)$ . Since  $3/(2-s)(1-s) \geq 3/2$ ,  $y_s^{Fd} \geq 0$  always holds for  $\gamma \leq 3/2$ , which implies that a duopoly always emerges for  $\gamma \leq 3/2$ .

For  $\gamma > 3/2$ , a duopoly is not feasible for  $3/(2-s)(1-s) \leq \gamma$ . Thus, firm N behaves as a constrained monopolist for  $3/(2-s)(1-s) \leq \gamma$ , or  $s \leq s_1$ , where

$$s_1 \equiv \frac{3 - (1 + 12/\gamma)^{1/2}}{2}. \quad (21)$$

The above results are summarized in the following lemma.

**Lemma 2** *When firm N decides to undertake FDI, (i) for  $\gamma \in (0, 3/2]$ , the market structure is duopoly; (ii) for  $\gamma \in (3/2, 4)$ , the market structure is foreign monopoly for  $s \leq s_1$  and duopoly for  $s > s_1$ .*

### 3.3.2 Export vs. FDI

Given the viable market structure in each regime, firm N decides whether to export or undertake FDI. Its choice depends on the efficiency of R&D. For  $\gamma \leq 3/2$ , a duopoly emerges, whether firm N exports or undertakes FDI. Substituting (10) into (4) yields

$$\pi_n^{Ed}(t^*) = \frac{(9 - 4\gamma)(a - c)^2}{(27 - 16\gamma)^2}. \quad (22)$$

From (17) and (22), firm N is indifferent between exporting and FDI if  $s = \bar{s}$ , where

$$\bar{s} \equiv 2 \left\{ 1 - \left( \frac{-64\gamma^2 + 207\gamma - 162}{\gamma(9 - 4\gamma)} \right)^{\frac{1}{2}} \right\}. \quad (23)$$

Note that  $-64\gamma^2 + 207\gamma - 162 > 0$  if and only if  $\gamma \in ((207 - 9\sqrt{17})/128, (207 + 9\sqrt{17})/128)$ , where  $(207 - 9\sqrt{17})/128 \approx 1.327$  and  $(207 + 9\sqrt{17})/128 \approx 1.907$ . Since  $d\bar{s}/d\gamma < 0$  for  $\gamma > (207 - 9\sqrt{17})/128$  and  $\bar{s} = 1$  if  $\gamma = \tilde{\gamma} \equiv 13/8 - \sqrt{217}/56 \approx 1.362$ , then  $\pi_n^{Fd}(s) > \pi_n^{Ed}(t^*)$  always holds for  $\gamma \leq \tilde{\gamma}$ . For  $\gamma \in [\tilde{\gamma}, 3/2]$ ,  $\pi_n^{Fd}(s) > (\text{resp. } <)$   $\pi_n^{Ed}(t^*)$  if  $s < (\text{resp. } >)$   $\bar{s}$ . Note that  $\bar{s} = 0$  when  $\gamma = 3/2$ .

For  $\gamma > 3/2$ , foreign monopoly emerges under exporting, while duopoly or foreign monopoly does under FDI, depending on  $s$ . Substituting (12) into (6) yields

$$\pi_n^{Em}(\bar{t}) = \frac{(9 - 4\gamma)(a - c)^2}{9}. \quad (24)$$

Then,  $\pi_n^{Em}(\bar{t})$  is equal to  $\pi_n^{Fd}(s)$ , which is given by (17), when  $s = s_2$ , where

$$s_2 \equiv 2 \left\{ 1 - 3 \left( \frac{2 - \gamma}{\gamma(9 - 4\gamma)} \right)^{\frac{1}{2}} \right\}. \quad (25)$$

Thus, if  $s \in (s_2, 1]$ ,  $\pi_n^{Em}(\bar{t}) > \pi_n^{Fd}(s) > \pi_n^{Fm}(s)$  holds. If  $s \in (s_1, s_2)$ ,  $\pi_n^{Fd}(s) > \pi_n^{Em}(\bar{t})$  and  $\pi_n^{Fd}(s) > \pi_n^{Fm}(s)$  hold. If  $s \in [0, s_1)$ ,  $\pi_n^{Fm}(s) > \pi_n^{Em}(\bar{t})$  and  $\pi_n^{Fm}(s) > \pi_n^{Fd}(s)$  hold. Note that  $s_2 > 1$  for  $\gamma \in (\check{\gamma}, 2]$ , where

$$\check{\gamma} \equiv \frac{45 - 3\sqrt{97}}{8} \approx 1.932. \quad (26)$$

$s_2$  becomes a complex number for  $\gamma > 2$ . Thus, for  $\gamma > \check{\gamma}$ , firm N never exports.

The above results are summarized in the following lemma:

**Lemma 3** (i) For  $\gamma \in (0, \tilde{\gamma}]$ , where  $\tilde{\gamma} \approx 1.362$ , firm N chooses FDI for all  $s \in [0, 1]$ ; (ii) For  $\gamma \in (\tilde{\gamma}, 3/2]$ , firm N chooses FDI if  $s \leq \bar{s}$  and exporting if  $s > \bar{s}$ ; (iii) For  $\gamma \in (3/2, \check{\gamma}]$ , firm N chooses FDI with foreign monopoly if  $s \leq s_1$ , FDI with duopoly if  $s \in (s_1, s_2]$ , and exporting if  $s > s_2$ ; (iv) For  $\gamma \in (\check{\gamma}, 4)$ , firm N chooses FDI with foreign monopoly if  $s \leq s_1$  and FDI with duopoly if  $s \in (s_1, 1]$ .

Firm N's choices of the mode of supply are drawn in figure 2. In figure 2,  $\gamma$  is taken in the horizontal axis and  $s$  is taken in the vertical axis. "FM" stands for "foreign monopoly." In the area left of the  $\bar{s}$  curve, firm N chooses duopoly under FDI, while in the area between the  $\bar{s}$  and  $s_2$  curves, firm N chooses exporting. In that area, the market structure is duopoly for  $\gamma \leq 3/2$  and foreign monopoly for  $\gamma > 3/2$ . Moreover, in the area right of the  $s_2$  curve, firm N chooses FDI. The market structure is duopoly above the  $s_1$  curve and foreign monopoly below the  $s_1$  curve.

Interestingly, firm N chooses FDI for both low and high  $\gamma$ , even when the Southern IPR protection is lax. When  $\gamma$  is low, since the size of the cost reduction is small, the damage for firm N from spillovers is likewise small. Thus, firm N prefers FDI to exporting

because the benefit from avoiding tariffs dominates the loss from spillovers. When  $\gamma$  is higher than  $3/2$ , the market structure under exporting is foreign monopoly. In that case, as  $\gamma$  rises, firm N's profits fall because it faces a higher tariff and hence has to invest in R&D more to become a monopolist. As is seen from (12) and (24),  $\bar{t}$  increases and  $\pi_n^{Em}(\bar{t})$  decreases as  $\gamma$  increases. In contrast,  $\pi_n^{Fd}$  increases as  $\gamma$  increases, which can be easily shown from (17). Because of these effects, for  $\gamma > 3/2$ , firm N tends to prefer FDI more as  $\gamma$  becomes higher. Note that the assumption that the Southern government imposes the optimal tariff is crucial for this result. As is seen from (6),  $\partial\pi_n^{Em}(t)/\partial\gamma > 0$ , which implies that if  $t$  is exogenously given, firm N's profits under exporting with foreign monopoly increase as  $\gamma$  increases.

## 4 The Optimal IPR Protection

In this section, I analyze the optimal IPR protection by the Southern government in stage 1. As shown above, firm N's choice of the mode of supply depends on the efficiency of R&D. Thus, I explore the optimal IPR policy for different levels of R&D efficiency.

### 4.1 Low R&D efficiency

I first examine the case of  $\gamma \leq 3/2$ . In this case, the market structure is a duopoly, whether firm N undertakes FDI or exporting. Under FDI, Southern welfare is given by

$$W^{Fd}(s) = \frac{(3 - \gamma(2 - s)(1 - s))^2(a - c)^2}{(9 - \gamma(2 - s)^2)^2} + \frac{(6 - \gamma(2 - s)(1 - s))^2(a - c)^2}{2(9 - \gamma(2 - s)^2)^2}. \quad (27)$$

Under exporting, Southern welfare is given by (11). Differentiating (11) with respect

to  $\gamma$  yields  $dW^{Ed}(t^*)/d\gamma = 6(a-c)^2/(27-16\gamma)^2 > 0$ . Since  $W^{Ed}(t^*)|_{\gamma=0} = 7(a-c)^2/18$  and  $W^{Ed}(t^*)|_{\gamma=3/2} = (a-c)^2/2$ , it holds  $W^{Ed}(t^*) \in [7(a-c)^2/18, (a-c)^2/2]$  for  $\gamma \leq 3/2$ .

The optimal IPR policy and the resulting market structure in SPNE are as follows.

**Proposition 1** *Define  $s^{**}$  by  $s^{**} \in \arg \max W^{Fd}(s)$ . (i) When  $\gamma \leq \tilde{\gamma} \approx 1.362$ , the optimal IPR policy is  $s = s^{**}$  and firm N chooses FDI; (ii) When  $\gamma \in (\tilde{\gamma}, 3/2]$ , the optimal IPR policy is (a)  $s = s^{**}$ , (b)  $s = \bar{s}$ , or (c) any  $s \in (\bar{s}, 1]$ . Firm N chooses FDI in (a) and (b) and exporting in (c).*

*Proof.* See the Appendix.

Three typical examples of the case in which  $\gamma \in (\tilde{\gamma}, 3/2]$  are drawn in figures 3, 4, and 5. In these figures,  $s$  is measured on the horizontal axis, and Southern welfare is measured on the vertical axis. In order to draw these figures, numerical simulations are run by normalizing  $(a-c)$  to one. The actual values of Southern welfare can be obtained by multiplying numbers in these figures by  $(a-c)^2$ . In each figure, the  $W^{Fd}$  curve and the  $W^{Ed}(t^*)$  curve are depicted. Since  $W^{Ed}(t^*)$  is independent of  $s$ , the  $W^{Ed}(t^*)$  curve is a horizontal line. Figure 3 shows the case of  $\gamma = 1.365$ . In this case,  $\bar{s} \approx 0.96$  and  $s^{**} \approx 0.75$ . Since firm N chooses FDI for  $s < \bar{s}$  and exporting for  $s > \bar{s}$ , the feasible part of each curve is as being thickened in the figure. Since  $s^{**} < \bar{s}$ , the optimal IPR policy is  $s = s^{**}$ , i.e., an interior solution. Figure 4 shows the case of  $\gamma = 1.4$ . In this case,  $\bar{s} \approx 0.59$  and  $s^{**} \approx 0.74$ . Since  $\bar{s} < s^{**}$ , the optimal IPR policy is  $s = \bar{s}$ , which is the lowest level of protection at which firm N undertakes FDI. Finally, figure 5 shows the case of  $\gamma = 1.45$ . In this case,  $\bar{s} \approx 0.24$  and  $s^{**} \approx 0.72$ . As shown in the figure,  $\bar{s}$

is lower than the  $s$  ( $\approx 0.43$ ) at which  $W^{Fd}(s) = W^{Ed}(t^*)$  holds. Thus, the welfare level in the feasible part of the  $W^{Fd}$  curve is lower than the value of  $W^{Ed}(t^*)$ , which implies that the optimal IPR policy is any  $s \in (\bar{s}, 1]$  to induce firm N to export.

## 4.2 Medium and high R&D efficiency

In the case of  $\gamma > 3/2$ , under FDI the market structure is either duopoly or foreign monopoly. I call the case of  $\gamma \in (3/2, \check{\gamma}]$  the “medium R&D efficiency” and the case of  $\gamma \in (\check{\gamma}, 4)$  the “high R&D efficiency,” where  $\check{\gamma}$  is defined by (26). Southern welfare under duopoly is given by (27). Southern welfare under foreign monopoly is given by

$$W^{Fm}(s) = \frac{(1-s)(a-c)^2}{2(1-2s)^2}. \quad (28)$$

Under exporting, from Lemma 1 the optimal tariff is  $\bar{t}$  and Southern welfare is given by

$$W^{Em}(\bar{t}) = W^{Ed}(\bar{t}) = \frac{(4\gamma-3)(a-c)^2}{6}. \quad (29)$$

The following lemma is then obtained.

**Lemma 4** (i)  $W^{Fd}(s_1) = W^{Fm}(s_1)$  for  $\gamma \in (3/2, 4)$ ; (ii)  $s_1 < s_2$  for  $\gamma \in (3/2, 2)$ ; (iii)  $dW^{Fm}(s)/ds > 0$  for  $s < 1/2$ ; (iv)  $W^{Fd}(s_1) \geq W^{Fd}(s)$  for all  $s \in [s_1, 1]$  and for  $\gamma \in (3/2, 4)$ ; and (v)  $W^{Fm}(s_1) < W^{Em}(\bar{t})$  for  $\gamma \in (3/2, 2]$ .

*Proof.* See the Appendix.

An important implication of Lemma 4 is that, with medium R&D efficiency, the South cannot improve its domestic welfare by manipulating its IPR protection policy so that firm N undertakes FDI and firm S stays in the market to extract the benefits of spillovers.

Using Lemmas 2 - 4, the following proposition is obtained for medium R&D efficiency.

**Proposition 2** *When  $\gamma \in (3/2, \check{\gamma}]$ , the optimal IPR protection is any  $s \in (s_2, 1]$ , where  $s_2$  is given by (25), and firm N chooses exporting.*

*Proof.* See the Appendix.

A typical example of medium R&D efficiency is drawn in figure 6, in which  $\gamma = 1.6$ . Basic features of figure 6 are the same as those of the previous three figures, except that in figure 6 three curves are depicted: the  $W^{Fd}$ ,  $W^{Fm}$ , and  $W^{Em}(\bar{t})$  curves. Since firm N chooses FDI with foreign monopoly for  $s < s_1$ , FDI with duopoly for  $s \in (s_1, s_2)$ , and exporting for  $s > s_2$ , the feasible part of each curve is as being thickened in the figure. The highest level of Southern welfare under FDI is given by the intersection between the  $W^{Fd}$  and  $W^{Fm}$  curves at  $s = s_1$ . However, that level of welfare is lower than  $W^{Em}(\bar{t})$ , which implies that the optimal IPR protection is characterized by any  $s \in (s_2, 1]$  to induce firm N to choose exporting.

For high R&D efficiency, the following proposition is obtained.

**Proposition 3** *When  $\gamma \in (\check{\gamma}, 4)$ , the optimal IPR protection is  $s = s_1$ , where  $s_1$  is defined by (21), and firm N chooses FDI with foreign monopoly.*

*Proof.* See the Appendix.

When  $\gamma \in (\check{\gamma}, 4)$ , all parts of the  $W^{Em}(\bar{t})$  curve are infeasible and hence the optimal IPR policy is  $s = s_1$ , which maximizes Southern welfare under FDI by inducing firm N to become the constrained monopolist.

Note that, unlike the case of low R&D efficiency, Propositions 2 and 3 show that spillovers never occur when the efficiency of R&D is medium or high. Note also that

when  $\gamma \geq 4$ , as was shown in Lemma 4,  $s_1$  is not well defined. In this case,  $y_n^{Fm}$  goes to infinity as  $s$  approaches  $1/2$ . Thus, the optimal IPR policy is also not well defined.

## 5 The Optimal IPR Protection with Strategic Tariff Policy

In this section, I discuss the case in which the Southern government chooses  $s$  and  $t$  in stage 1. As I have argued above, when a tariff is set before firm N's location choice, the Southern government may strategically impose an excessive tariff to induce firm N to undertake FDI. It may also strategically impose a lower tariff to induce firm N to export if Southern welfare is higher under exporting but firm N prefers FDI under the optimal tariff. Except for these strategic roles, the optimal tariff is the same as that in section 3.1.4, because tariffs do not affect the outcomes in the subgames under FDI.

Now, define  $\underline{\gamma}$  by  $W^{Ed}(t^*; \underline{\gamma}) = W^{Fd}(s^{**}; \underline{\gamma})$ . It is shown that  $\underline{\gamma} \approx 1.478$ . Then, for  $\gamma \in (0, \underline{\gamma}]$ ,  $W^{Ed}(t^*; \gamma) < W^{Fd}(s^{**}; \gamma)$  holds. The optimal policy is a combination of  $s = s^{**}$  and any  $t$  such that  $\pi_n^{Ed}(t) < \pi_n^{Fd}(s^{**})$ . Firm N chooses FDI and Southern welfare is  $W^{Fd}(s^{**}; \gamma)$ . For  $\gamma \in (\underline{\gamma}, 3/2]$ , it holds that  $W^{Ed}(t^*; \gamma) > W^{Fd}(s; \gamma), \forall s$ . Figure 7 shows an example of this case where  $\gamma = 1.49$ . The optimal policy is a combination of any  $s \in (\bar{s}, 1]$  and  $t = t^*$ , which yields the same outcome as Proposition 1 (ii) (c). Firm N chooses exporting and Southern welfare is  $W^{Ed}(t^*; \gamma)$ . Compared with Proposition 1, choosing  $t$  at stage 1 enables the South to attract FDI whenever Southern welfare is higher under FDI. For some parameter values, a laxer IPR policy is chosen, compared with the case where a tariff is set after firm N's decision to export.

For  $\gamma \in (3/2, \check{\gamma}]$ , the highest possible Southern welfare under exporting is  $W^{Em}(\bar{t})$

and that under FDI is  $W^{Fm}(s_1)$ . From Lemma 4 (v),  $W^{Fm}(s_1) < W^{Em}(\bar{t})$  holds for  $\gamma \in (3/2, 2]$ . Consequently, the optimal policy is a combination of any  $s \in (s_2, 1]$  and  $t = \bar{t}$ , which yields the same outcome as Proposition 2.

Define  $\tilde{t}$  by  $\pi_n^{Em}(\tilde{t}) = \pi_n^{Fd}|_{s=1}$ . Note that  $\tilde{t} \leq \bar{t}$  holds. Also, define  $\hat{\gamma}$  by  $W^{Fm}(s_1) = W^{Em}(\tilde{t}; \hat{\gamma})$ . It is shown that  $\check{\gamma} < \hat{\gamma} < 2.1$  holds. Then, for  $\gamma \in (\check{\gamma}, \hat{\gamma}]$ , Southern welfare is higher under exporting, while firm N chooses FDI even with  $s = 1$  if  $t = \bar{t}$ . The Southern government tries to induce firm N to export by lowering the tariff from  $\bar{t}$  and setting the lowest IPR protection. The optimal policy is a combination of  $s = 1$  and  $t = \tilde{t}$ . Firm N chooses exporting with foreign monopoly and Southern welfare is  $W^{Em}(\tilde{t}; \hat{\gamma})$ . Moreover, for  $\gamma \in (\hat{\gamma}, 4)$ , since  $W^{Fm}(s_1) > W^{Em}(\tilde{t}; \hat{\gamma})$ , the Southern government has no further incentive to induce firm N to export. The optimal policy is a combination of  $s = s_1$  and any  $t$  such that  $\pi_n^{Em}(t) < \pi_n^{Fm}(s_1)$ . The outcome is the same as Proposition 3. Thus, the result is different from Proposition 3 only in the range of  $\gamma \in (\check{\gamma}, \hat{\gamma}]$ , in which the South strategically chooses a lower tariff to induce firm N to export.

## 6 Concluding Remarks

In this paper, I have investigated the optimal choice of IPR protection policy by a Southern country when a Northern and a Southern firm compete in the Southern market. The Northern firm engages in cost-reducing R&D, which may allow knowledge spillover to the Southern firm, depending on the level of the Southern IPR protection policy. When the Northern firm undertakes FDI to produce locally in the South, technological spillovers occur. When the Northern firm produces in the North and exports goods to

the South, on the other hand, technological spillovers would not occur. Under exporting, however, the Northern firm faces a tariff optimally set by the Southern government.

Unlike the results of Žigić (2000) and Naghavi (2006), I have shown that for certain parameter values the optimal IPR protection policy by the South is characterized by an interior solution, which is more stringent than the level at which the Northern firm is just indifferent between exporting and undertaking FDI. Moreover, unlike Naghavi (2006), I have also shown that the South does not always try to attract FDI. For certain parameter values, the South prefers the Northern firm to engage in exporting rather than undertaking FDI, though technological spillovers do not take place.

For future research, there are a number of potentially interesting extensions of the analysis. First, I have considered only costless spillovers of technology. In the real world, many firms engage in costly imitation activities. A number of studies, including Helpman (1993), Lai (1998), and Glass and Saggi (2002), have examined imitation and IPR protection. Thus, it is practically important and perhaps theoretically interesting to extend the analysis by introducing a costly imitation by the Southern firm. Second, although the appropriability of innovation is set exogenously by the strength of Southern IPR policy in this paper, it may be quite interesting to endogenize the appropriability regime by considering the possibility of “masking” product technology by the Northern firm, as Taylor (1993) did. Third, as Chin and Grossman (1990) have examined, the possibility of licensing superior technology can be introduced. Licensing is also an important source of obtaining superior technology for developing countries. Empirical studies (Smith, 2001; Nagaoka, 2004) suggest that IPR protection affects international licensing.

## A Appendix: Proofs of Lemmas and Propositions

### A.1 Proof of Lemma 1

(i) For  $\gamma \in (0, 3/2]$ , since monopoly by firm N is not feasible, the possible market structure is only duopoly and domestic monopoly. From (7) and (11), it yields that

$$W^{Ed}(t^*) - W^{Ep} = \frac{3(7 - 4\gamma)(a - c)^2}{2(27 - 16\gamma)} - \frac{3(a - c)^2}{8} = \frac{3(a - c)^2}{8(27 - 16\gamma)} > 0.$$

(ii) For  $\gamma \in (3/2, 9/4)$ ,  $W^{Ed}(t) >$  (resp.  $<$ )  $W^{Em}(t)$  holds for  $t <$  (resp.  $>$ )  $\bar{t}$ . Since duopoly is feasible only for  $t > \bar{t}$ , the highest possible welfare level is attained when  $t = \bar{t}$ , which is given by (29). From (7) and (29), it yields that

$$W^{Em}(\bar{t}) - W^{Ep} = \frac{(4\gamma - 3)(a - c)^2}{6} - \frac{3(a - c)^2}{8} = \frac{(16\gamma - 21)(a - c)^2}{24},$$

which is positive for  $\gamma > 21/16 \approx 1.313$ . ■

### A.2 Proof of Proposition 1

(i) When  $\gamma \leq \tilde{\gamma}$ , from Lemma 3 firm N chooses FDI for all  $s \in [0, 1]$ . By definition  $s = s^{**}$  is optimal. (ii) When  $\gamma \in (\tilde{\gamma}, 3/2]$ , if  $s^{**} < \bar{s}$  and  $W^{Ed}(t^*) < W^{Fd}(\bar{s})$ ,  $s^{**}$  is optimal and firm N chooses FDI. If  $\bar{s} < s^{**}$  and  $W^{Ed}(t^*) < W^{Fd}(\bar{s})$ , the optimal  $s$  is just to induce firm N to undertake FDI, which is given by  $\bar{s}$ , and firm N chooses FDI. If  $\bar{s} < s^{**}$  and  $W^{Ed}(t^*) > W^{Fd}(\bar{s})$  or if  $s^{**} < \bar{s}$  and  $W^{Ed}(t^*) > W^{Fd}(s^{**})$ , Southern welfare is higher under exporting. Thus, any  $s$  that leads to exporting is optimal. ■

### A.3 Proof of Lemma 4

(i) By definition,  $\pi_n^{Fd}(s_1) = \pi_n^{Fm}(s_1)$  holds, which implies that  $y_n^{Fd}(s_1) = y_n^{Fm}(s_1)$  and that  $x^{Fd}(s_1) = x^{Fm}(s_1)$ . It also implies that  $y_s^{Fd}(s_1) = 0$ . Thus,

$$W^{Fd}(s_1) = \pi_s^{Fd}(s_1) + \frac{(y_n^{Fd}(s_1) + y_s^{Fd}(s_1))^2}{2} = \frac{(y_n^{Fm}(s_1))^2}{2} = W^{Fm}(s_1).$$

From (19),  $y_n^{Fm}$  is non-negative and finite only for  $s < 1/2$ . Similarly, from (17) and (20), both  $y_n^{Fd}$  and  $y_s^{Fd}$  are non-negative and finite only for  $s > s_1$  and  $s > 2 - 3/\gamma^{1/2}$ . This implies that for  $\gamma \geq 4$ ,  $s > 1/2$  is necessary for non-negative and finite  $y_n^{Fd}$  and  $y_s^{Fd}$ . Hence, for  $\gamma \geq 4$ ,  $s_1$  is not well defined.

(ii) From (21) and (25), it yields that

$$\begin{aligned} s_2 - s_1 &= 2 \left\{ 1 - 3 \left( \frac{2 - \gamma}{\gamma(9 - 4\gamma)} \right)^{\frac{1}{2}} \right\} - \frac{3 - (1 + 12/\gamma)^{1/2}}{2} \\ &= \frac{\gamma^{1/2}(9 - 4\gamma)^{1/2} + (9 - 4\gamma)^{1/2}(12 + \gamma)^{1/2} - 12(2 - \gamma)^{1/2}}{2\gamma^{1/2}(9 - 4\gamma)^{1/2}}, \end{aligned}$$

which is shown to be zero when  $\gamma = 3/2$  and positive for  $\gamma \in (3/2, 2)$ .

(iii) Differentiate  $W^{Fm}(s)$  with respect to  $s$  to yield  $dW^{Fm}(s)/ds = (1-s)(a-c)^2/(1-2s)^3$ , which is positive for  $s < 1/2$ .

(iv) It is easily shown that  $s_1|_{\gamma=3/2} = 0$ ,  $ds_1/d\gamma = 3/\gamma^2(1 + 12/\gamma)^{1/2} > 0$ , and  $s_1|_{\gamma=4} = 1/2$ . Differentiate (27) with respect to  $s$  to obtain

$$\frac{dW^{Fd}(s)}{ds} = -\frac{3\gamma\{36(1-s) - \gamma(2-s)(19 - 25s + 10s^2) + \gamma^2(1-s)(2-s)^3\}(a-c)^2}{(9 - \gamma(2-s)^2)^3}.$$

It is shown that  $dW^{Fd}(s)/ds$  evaluated at  $\gamma = 3/2$  has a local minimum at  $s \approx 0.167$  and a local maximum at  $s \equiv s^{\max} \approx 0.685$ . Since  $W^{Fd}(0)|_{\gamma=3/2} = (a-c)^2/2$  and  $W^{Fd}(s^{\max})|_{\gamma=3/2} \approx 0.480 \times (a-c)^2$ , then for  $\gamma = 3/2$ ,  $W^{Fd}(s_1) \geq W^{Fd}(s)$  holds for all

$s \in [s_1, 1]$ . For  $1.5 < \gamma \leq 1.696$ , a proof is given in a similar way. For  $1.696 < \gamma < 4$ ,  $dW^{Fd}/ds < 0$  for all  $s \in [s_1, 1]$ . Thus,  $W^{Fd}(s_1) \geq W^{Fd}(s)$  holds for all  $s \in [s_1, 1]$ .

(v) Use (29) and substitute (21) into (28) to obtain

$$\begin{aligned} W^{Em}(\bar{t}) - W^{Fm}(s_1) &= \frac{(4\gamma - 3)(a - c)^2}{6} - \frac{(1 - s_1)(a - c)^2}{2(1 - 2s_1)^2} \\ &= \frac{(4\gamma - 3)(a - c)^2}{6} - \frac{(\gamma - \gamma^{1/2}(\gamma + 12)^{1/2})^2(a - c)^2}{8(2\gamma - \gamma^{1/2}(\gamma + 12)^{1/2})^2}, \end{aligned}$$

which is shown to be zero when  $\gamma = 3/2$  and positive for  $\gamma \in (3/2, 2]$ . ■

#### A.4 Proof of Proposition 2

From Lemma 2 (ii), when firm N undertakes FDI, the market structure is foreign monopoly for  $s \leq s_1$  and a duopoly for  $s > s_1$ . Then, from Lemma 4 (i)-(iv), the highest level of Southern welfare under FDI is given by  $W^{Fd}(s_1) = W^{Fm}(s_1)$ . However, from Lemma 4 (v),  $W^{Fd}(s_1) = W^{Fm}(s_1) < W^{Em}(\bar{t})$  holds, which implies that Southern welfare is highest when firm N exports. Since  $W^{Em}(\bar{t})$  is independent of  $s$  and since  $s > s_2$  induces firm N to export, the optimal IPR policy is any  $s \in (s_2, 1]$  if  $s_2 \leq 1$ . ■

#### A.5 Proof of Proposition 3

From Lemma 3 (iv), for  $\gamma > \check{\gamma}$ , firm N never chooses exporting. Moreover, from Lemma 2 (ii), when FDI is undertaken, the market structure is foreign monopoly for  $s \leq s_1$  and a duopoly for  $s > s_1$ . Then, from Lemma 4 (i), (iii), and (iv), the optimal IPR policy is given by  $s = s_1$  in the range of  $\gamma \in (\check{\gamma}, 4)$ . ■

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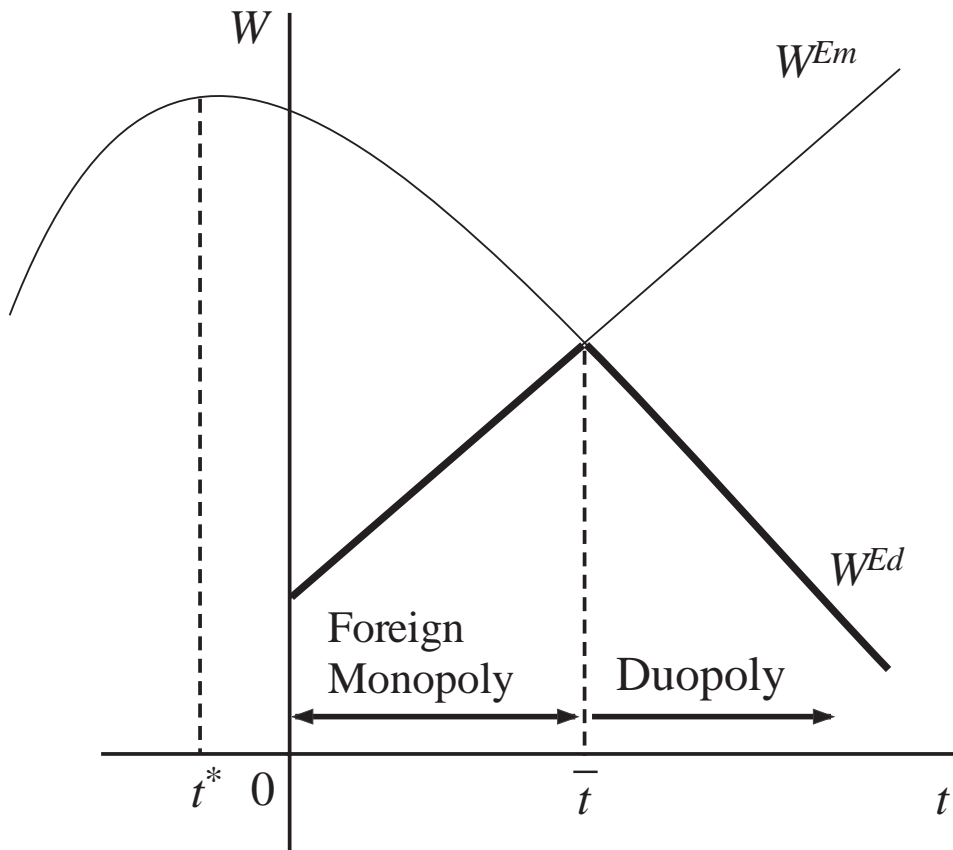


Figure 1: The optimal tariff for  $\gamma \in (3/2, 9/4)$

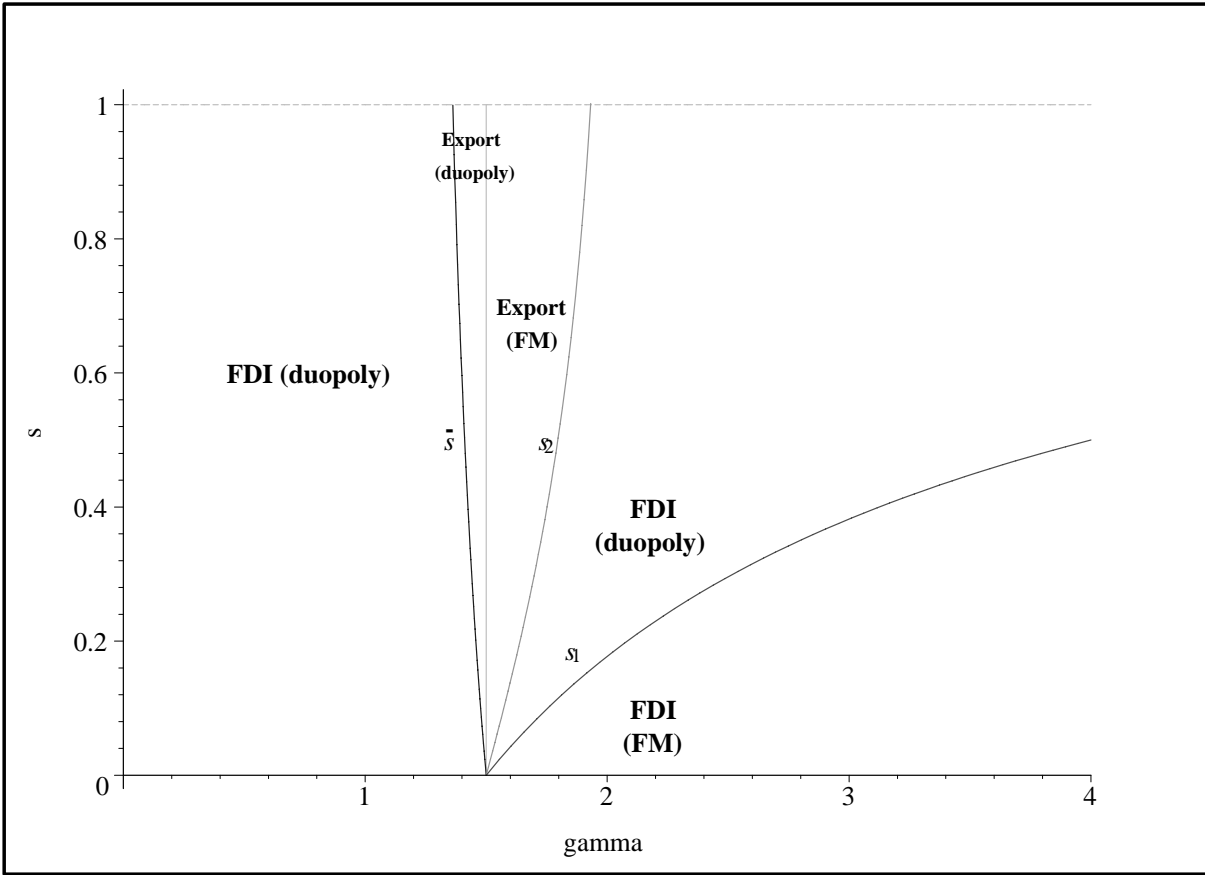


Figure 2: Firm N's choices of mode of supply

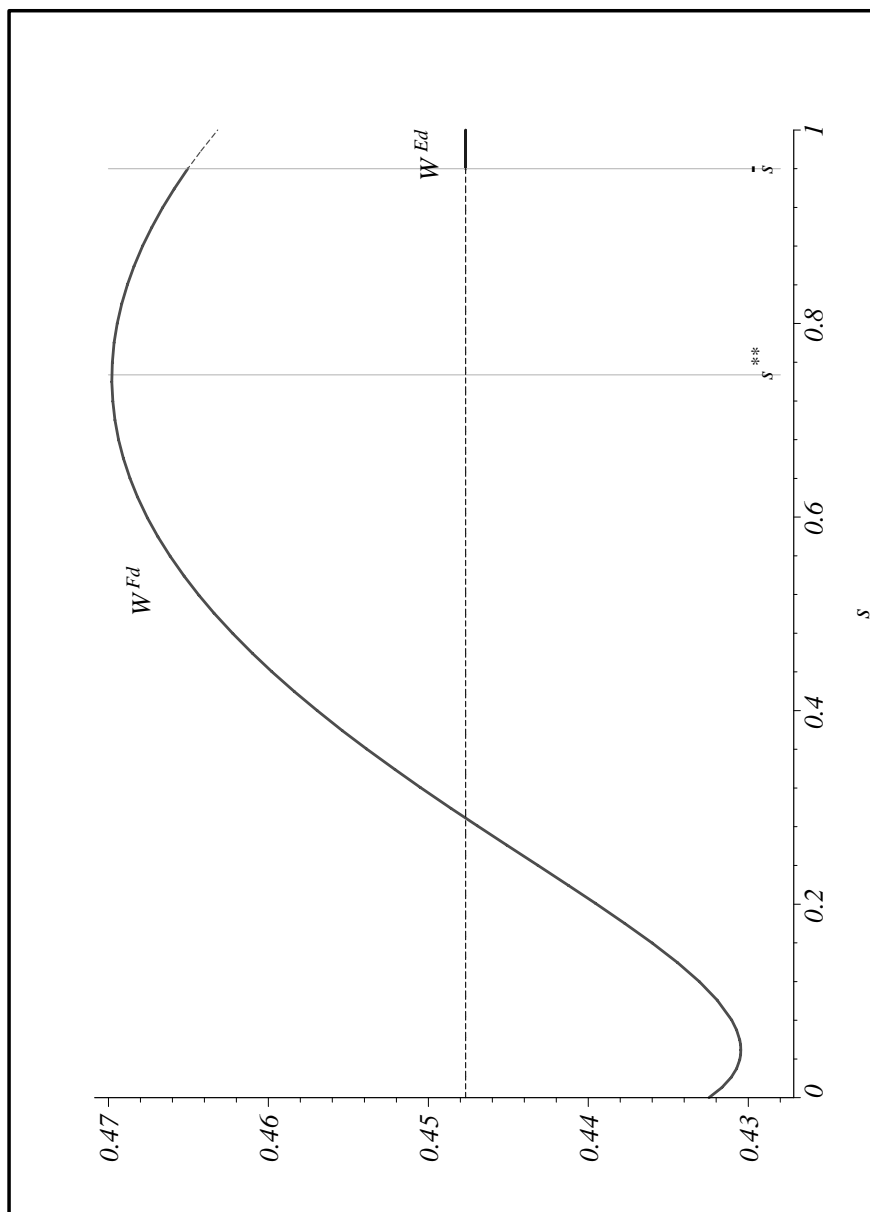


Figure 3: The optimal IPR protection policy:  $\gamma = 1.365$ .

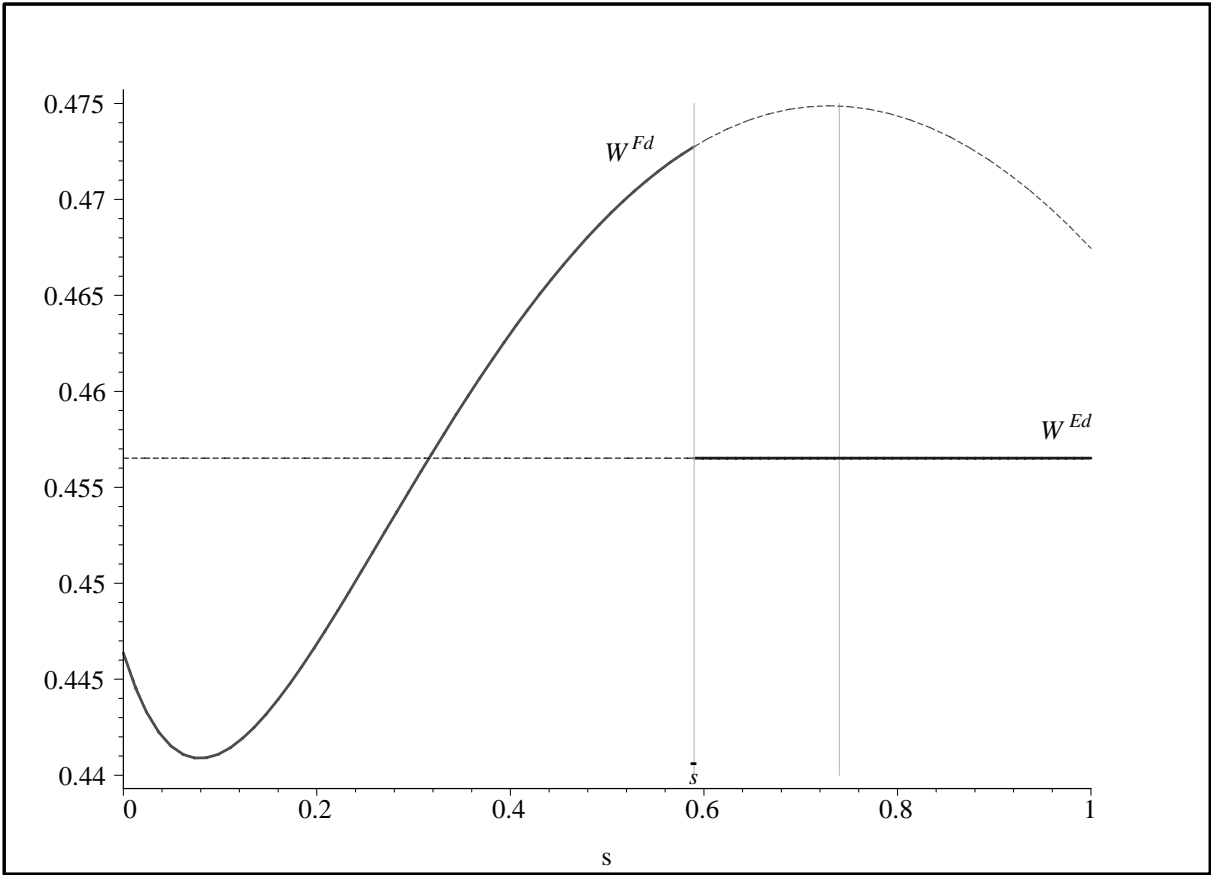


Figure 4: The optimal IPR protection policy:  $\gamma = 1.4$ .

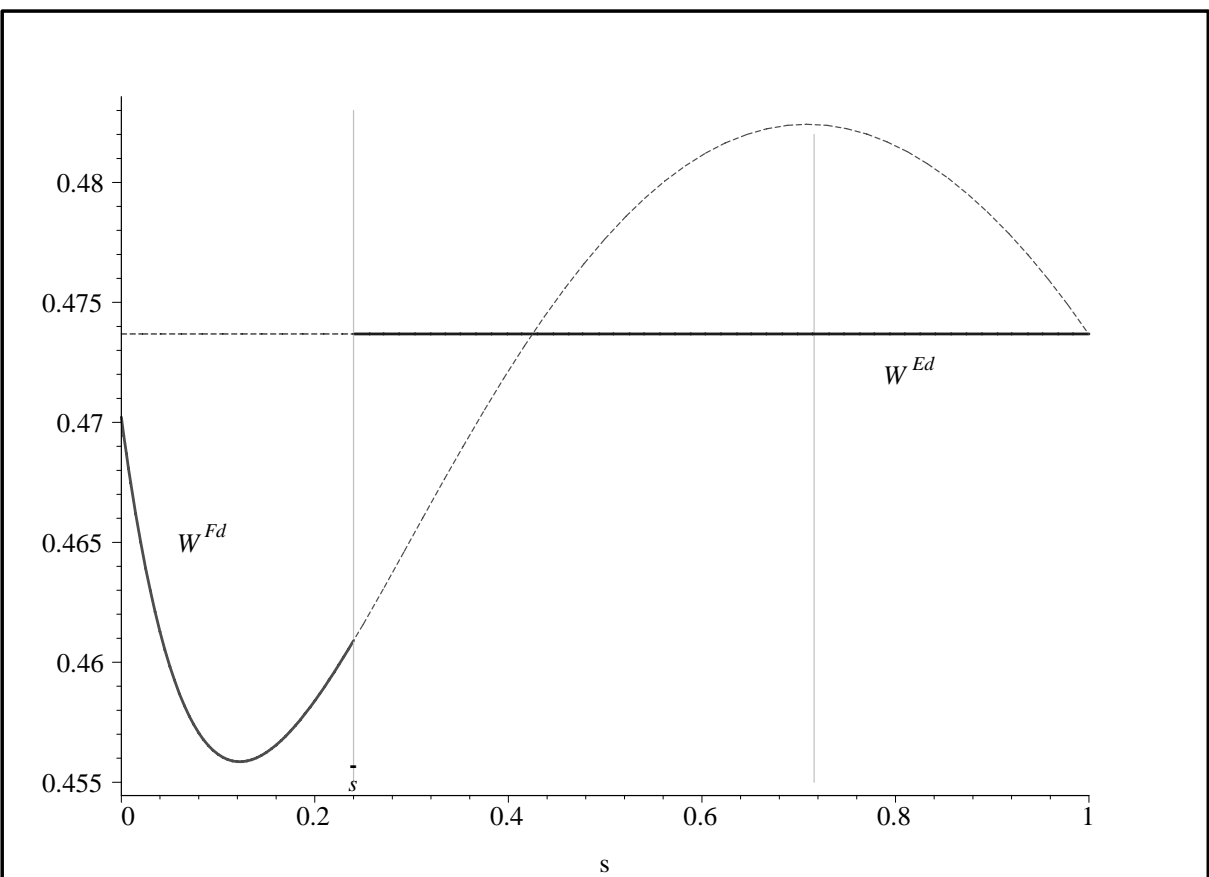


Figure 5: The optimal IPR protection policy:  $\gamma = 1.45$ .

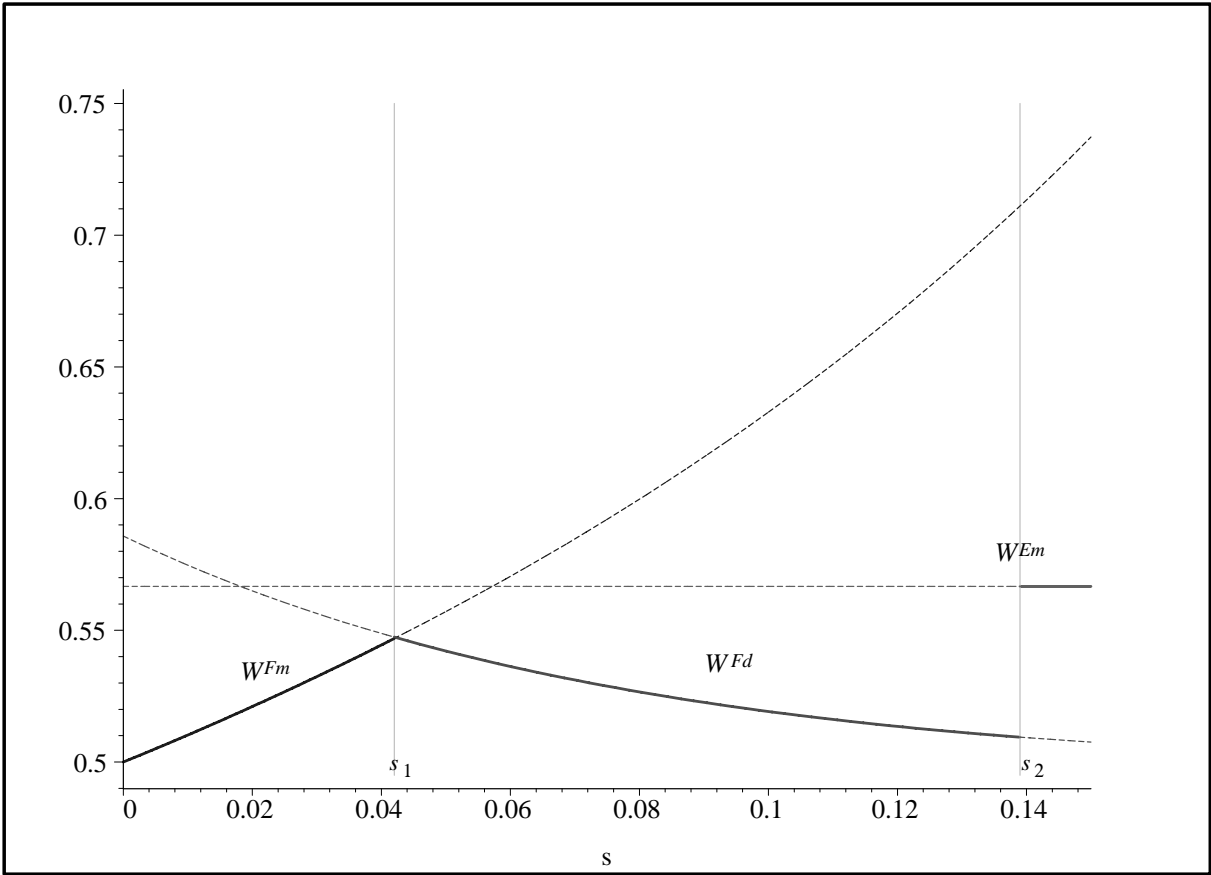


Figure 6: The optimal IPR protection policy:  $\gamma = 1.6$ .

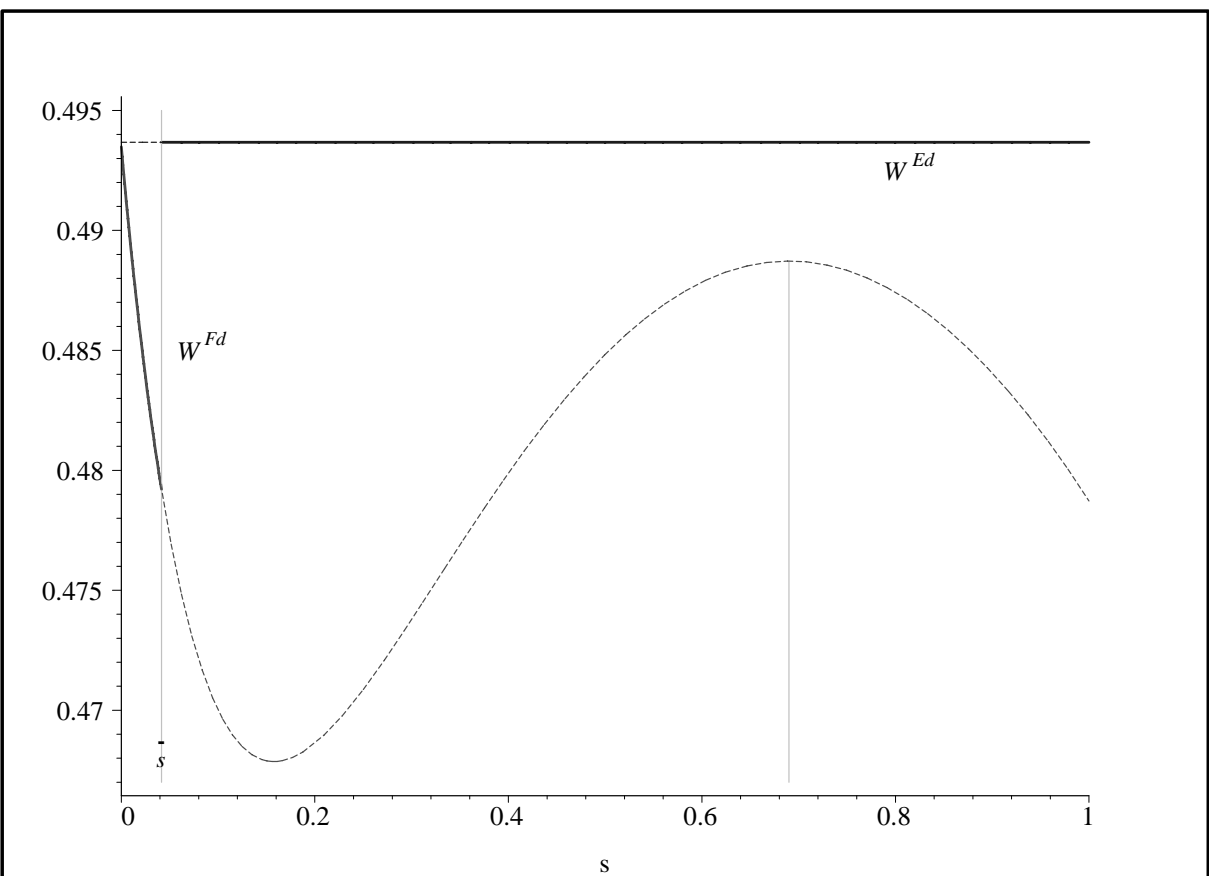


Figure 7: The optimal IPR protection policy:  $\gamma = 1.49$ .