Strategic Enforcement, Intellectual Property Rights and Contractual R&D

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Abstract

This paper examines the role of intellectual property rights (IPRs) in contractual R&D in developing countries. We find that strong IPRs provide incentives for firms, both multinational and local, to specialize in R&D activities in which they have competitive advantage (the *specialization effect*). They also facilitate the switching process from imitators to potential innovators for local firms (the *switching effect*). Moreover, we also demonstrate that a multinational firm's strategic IPRs enforcement behavior can be an effective instrument for subsidizing contractual R&D in developing countries (the *subsidizing effect*). We further illustrate how a policy mix of IPRs and a foreign direct investment subsidy in these countries affects R&D activities by adding an offshore R&D subsidiary as an additional organizational form.

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1. Introduction

In recent decades, globalization has led to the fragmentation of production across national borders, with each country specializing in a particular stage of the production process. More recently, this pattern of internationalization has extended from production to further up the value chain, that is, to research and development (R&D) activities, with each country specializing in a particular stage of the R&D chain.

How should a developing country reform its intellectual property rights (IPRs) policy to render it more conducive to outsourced R&D activities in the era of globalization? We build a theoretical model to answer this question. We consider a model in which two firms in a developing country, one multinational (firm N) and one local (firm S), produce a product that is composed of two components. The multinational firm and local firm have a competitive advantage in carrying out R&D on component 1 and component 2, respectively. The multinational firm always undertakes R&D on component 1 because of its competitive advantage. The local firm, however, can either engage in R&D on component 2, and license the resulting technology to the multinational firm as a subcontractor, or imitate the multinational's component 1 technology as an imitator without undertaking contractual R&D. The choice depends on the strength of IPRs in the host developing country. In a three-stage game, we obtain the following results.

First, we demonstrate that strong IPRs in developing countries may induce both multinational and local firms to specialize in one stage of R&D, that is, there is a *specialization effect* that can be attributed to a strong IPRs regime. Second, our results suggest the possibility that an original imitator in developing countries can eventually

become an innovator, with strong IPRs thus inducing a *switching effect*. Third, in contrast to conventional wisdom, our results suggest that a multinational firm's strategic IPRs enforcement can be used as an effective instrument to subsidize contractual R&D in developing countries, thereby benefiting both local and multinational firms (the *subsidizing effect*). Fourth, strong IPRs can boost the welfare of developing countries when contractual R&D generates substantial cost-savings and the bargaining position of local firms is relatively strong. Finally, we illustrate the way in which a policy mix of IPRs and a foreign direct investment (FDI) subsidy in developing countries affects contractual R&D by adding an offshore R&D subsidiary as an additional organizational form.

Our interest in contractual R&D is motivated by the recent surge in international fragmentation in R&D. There is considerable evidence of this new trend in a variety of industries. In the pharmaceutical industry, for example, the largest multinationals, including Merck, Eli Lilly, and Johnson & Johnson, are partnering with firms in the developing world to carry out sophisticated drug research and clinical testing (Wadhwa 2008a), and Hutchison MediPharma, a Chinese firm, has formed an R&D partnership with Eli Lilly (Wadhwa 2008b). The information technology (IT) industry has also witnessed the rapid expansion of offshore R&D outsourcing. Many multinational IT firms, including Dell, Motorola, and Philips, are not only purchasing cell phones from Asian developers but also the complete designs of digital services. In the aerospace industry, Boeing Co. is working with India's HCL Technologies to co-develop software for everything from navigation systems and landing gear to the former's 7E7 Dreamliner jet (Engardio and Einhorn 2005).

Data on licensing payments also show a boost in contractual R&D between multinationals and local firms in developing countries. For example, U.S. licensing payments to Chinese firms rose from US$1 million in 1995 to US$13 million in 2000, reaching US$115 million in 2007. Over the same period, U.S. licensing payments to Indian firms rose from $2 million to US$98 million.[1] China's official balance of payment statistics show the total licensing fee payments received by Chinese firms to have registered a substantial increase over the period, rising from US$82 million in 2000 to US$343 million in 2007.

The proliferation of international specialization in R&D activities can be attributed to the following factors. First, several developing countries, India, China, and Brazil in particular, have succeeded in building up their R&D capacity in recent years, thereby reducing the technology gap between themselves and developed countries. Second, R&D in certain industries, the pharmaceutical industry for example, is highly complex and prohibitively expensive. The intensification of globalization has put multinational firms under pressure to reduce their R&D costs. Such factors as lower labor costs, time savings due to the time difference between developed and developing countries, higher patient enrolment rates, and the prevalence of a wide variety of diseases and heterogeneous gene pool all contribute to the cost advantage enjoyed by developing nations in the drug research process.[2] Hence, the strategy adopted by many multinational firms is to specialize in a particular component of the R&D chain to reduce R&D costs.

[1] These data are from the U.S. Department of Commerce, available at http://www.bea.gov/international/intlserv.htm.

[2] For example, it was estimated to cost the pharmaceutical industry about US$800 million to bring a new molecular entity to the market in 2005, a significant portion of which was spent on testing the drug on patients prior to commercial approval. A 2004 McKinsey study suggests that the cost-savings realized in the drug research process would be about US$200 million if clinical trials were carried out in India. See *The Hindu Survey of Indian Industry 2004*, available at http://www.thehindu.com.

Our paper builds on the body of literature concerning the role played by IPRs in developing countries in innovation and economic growth. There are mixed views on IPRs policies in these countries. On the one hand, there are concerns that strengthening IPRs may not be in the interests of developing countries, as stronger IPRs lead to increased imitation costs for southern firms (Chin and Grossman 1990), a reduction in consumer surpluses owing to monopoly pricing (Deardorff 1992), and the diminishing of both developed countries' rates of innovation and developing countries' welfare in the long run (Helpman 1993). On the other hand, recent studies suggest that strong IPRs may benefit developing countries, as they encourage the inward flow of technology, close the gap in technological sophistication between these countries and their developed counterparts, and lead to the flowering of local innovation (e.g., Maskus 1995, 2000).

None of the aforementioned studies, however, touches upon the influence on contractual R&D activities of stronger IPRs in developing countries. Our paper fills this gap in the literature by establishing a link between IPRs and international contractual R&D, thereby offering a new perspective on IPR protection in developing countries.

This paper is also related to the literature on the link between IPRs and domestic innovations in developing countries. Chen and Puttitanun (2005) find that although stronger IPRs encourage domestic innovation, they also make it more difficult for a domestic imitator to imitate a more advanced foreign firm's technology in the import sector. Hence, developing countries need to balance these two effects in determining their IPR policies. Mukherjee and Sinha (2013) show that stronger IPRs in the South may render a northern firm worse off and a southern firm better off by increasing the latter's incentives to innovate. Our paper complements this line of inquiry by focusing on the

following factors. First, we consider the role of IPRs in a context in which both multinational and local firms have competitive advantage in one stage of the R&D chain. Therefore, we focus on the case of multinational and local firms innovating on different components rather than the same one. Second, we consider the possibility that an original imitator in a developing country may switch to being an innovator. Third, we show the implications of strategic IPRs enforcement.

Finally, this paper is also associated with the strand of literature on IPRs and R&D competition. Chowdhury (2005) argues that patent protection reduces R&D investment if the tournament effect is negative. Mukherjee (2006) shows that the effect of either imitation or technology licensing can dominate the tournament effect and create higher R&D investment under patent protection.

The remainder of the paper is organized as follows. In Section 2, we present a basic model of contractual R&D. We analyze the equilibrium results under no patent protection, strong patent protection, and strategic IPRs enforcement in Section 3. The effects of changes in IPRs regimes on southern welfare are investigated in Section 4. We further examine how the results change with the addition of an R&D subsidiary in Section 5, and offer concluding remarks in Section 6.

2. The basic setup

In this section, we outline a model that captures the current features of the internationalization of R&D activities. Consider a market with two firms, N (a multinational firm) and S (a local firm),[4] that produce a homogeneous product using two

[4] Our findings remain qualitatively unchanged with different numbers of southern firms engaging in quantity competition.

components and compete in Cournot fashion in the South. If a represents the market size of the South, then the inverse-demand function for the product is given by $P = a - q$, where P is the price of the product and q is the quantity produced.[5] Let c_i ($i = 1,2$) denote the firms' marginal production costs related to the first and second components before process innovation or imitation.[6] The marginal production costs related to component i can be reduced to $\tilde{c}_i$ through process innovation and to $\alpha\tilde{c}_i$ through imitation. Here, α is a parameter representing firms' imitation capacity given by such characteristics of the South as education level and infrastructure, with a lower value of α indicating greater imitation capacity. Because the imitator has no access to tacit knowledge, including know-how and information gained from experience, we have $\alpha > 1$. Hence, we have $\tilde{c}_i < \alpha\tilde{c}_i < c_i$. Thus, both imitation and innovation reduce the firms' marginal cost, although the decline is greater in the latter case.

Assume that firm N has competitive advantage in conducting R&D on component 1 because it enjoys a higher technological level and that firm S has competitive advantage in conducting R&D on component 2 because it enjoys the advantage of lower labor costs and some of the other advantages discussed in the introduction. To focus our analysis on the firms' incentives to engage in contractual R&D, we assume that N alone carries out process innovation on component 1 before the game starts. We also assume that N produces in the North, and S in the South.[7] Let R_N and R_S denote the component 2 R&D

[5] We assume market size a to be sufficiently greater than marginal costs to ensure positive production for both firms.

[6] The R&D we consider in this paper is cost-reducing R&D, or process innovation, as most contractual R&D activities in developing countries are targeted at cost reduction rather than quality improvement.

[7] In this paper, we have chosen to focus on the effects of a change in IPR regime on contractual R&D activities between the North and the South. Therefore, such issues as the trade of final and intermediate goods and the offshore outsourcing of production are beyond its scope.

costs of firms N and S, respectively. Here, we assume that $R_S < R_N$, thus reflecting firm S's competitive advantage in carrying out R&D on component 2. Therefore, firm N can either undertake in-house R&D on this component or outsource it to firm S. If the offshore outsourcing of R&D occurs, then we assume that N offers a take-it-or-leave-it contract with a lump-sum license fee to S, which accepts that contract if it will not become worse off by doing so.[9] Consequently, firm S obtains its reservation value, and all of the surplus accrues to firm N. We denote by *L* the lump-sum license fee that must be paid to acquire the component 2 technology innovated by firm S.

Here, we describe the decision structure of the game in which there are two players: firms S and N. The game's time sequence is as follows. In stage 1, firm N chooses between undertaking in-house R&D on component 2 and offering an R&D contract to firm S. If N chooses in-house R&D in stage 1, firm S chooses one of three strategies in stage 2: (i) imitating the component 1 technology without undertaking R&D on component 2 (denoted by s(i) in the game tree); (ii) forgoing the imitation of the component 1 technology while conducting R&D on component 2 (denoted by s(ii) in the game tree); or (iii) imitating the component 1 technology while conducting R&D on component 2 (denoted by s(iii) in the game tree).[10] Both firms maximize their profits by

[9] Our specification of a lump-sum license fee without per-unit royalties mirrors the technology contracts that are prevalent in the developing world. For example, Vishwasrao (2007) assembled data on all foreign technology licensing agreements entered into by manufacturing firms unaffiliated with the licensors in India between 1989 and 1993. In the 1991-1993 period, there were 968 contracts specifying only lump-sum fees, accounting for 45 percent of all licensing deals in the sample.

[10] Because of the assumption that $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, c_S)$, strategy (ii) will always dominate a strategy of no imitation and no innovation, which is a potential fourth strategy. This assumption is made to minimize technical details that are not essential for our results. Our findings remain unchanged if we relax the assumption.

simultaneously choosing optimal quantities in a Cournot setting, with profits realized in stage 3. [11]

If firm N offers an R&D contract in stage 1, firm S chooses whether to accept it in stage 2, given the southern patent scope. If the contract is accepted in stage 2, S then chooses whether to imitate N's component 1 technology in stage 3, and both firms maximize profits by simultaneously choosing optimal quantities in stage 4. If the contract is rejected in stage 2, then S chooses from among strategies (i), (ii), and (iii) in stage 3. Both firms maximize profits by simultaneously choosing optimal quantities in stage 4.

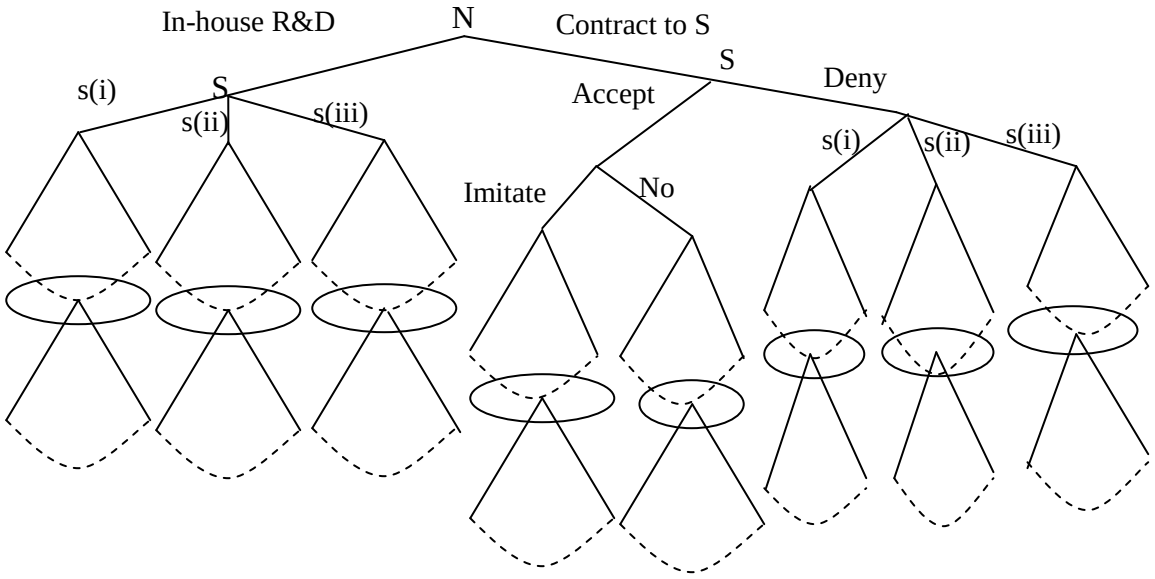

Figure 1: The Stages of the Game

[11] We rule out the possibility that firm N can imitate firm S's technology on component 2 to avoid complicating the model. One practical justification for doing so is that firm S applies for a patent on its technology in both developing and developed countries, thus rendering it more difficult for N to imitate S's technology because developed countries have much stronger patent protection.

In the absence of a contractual relationship, we assume that the imitation of firm N's component 1 technology can be achieved through product inspection, reverse engineering, or simple trial and error, with S paying the related imitation costs. Stronger IPRs make it harder for S to imitate N's product either because the broader patent scope limits reverse engineering or because there is greater enforcement against infringement. Let I_0 and I_0' denote firm S's imitation cost in the absence of a contractual relationship under weak and strong patent protection respectively, where $I_0 < I_0'$.

In the presence of a contractual relationship, firm S has access to firm N's component 1 technology, as N has to reveal information on that component to S to facilitate the latter's innovation on component 2. In this event, firm N will apply injunctive remedies to deter imitation by firm S. The magnitude of these remedies depends on the strength of the patent protection in S's country. Thus, firm S's imitation incentive when there is a contractual relationship also depends on the strength of patent protection. Let I_1 and I_1' denote S's imitation costs when there is such a relationship in the form of fines from injunctive remedies under weak and strong patent protection, respectively, giving us $I_1 < I_1'$.

In this context, we assume that $f(\ ,\ )$ represents the relationship between the marginal production costs of the components and the marginal production costs of the product, where the first (second) argument is the marginal cost of component 1 (component 2).[14] Suppose that firm N's marginal production costs of the product are c_N and $\tilde{c}_N$ in the absence and presence of process R&D on component 2, respectively. Thus,

[14] The precise form of $f(\ ,\ )$ is not crucial for our results.

we have $c_N = f(\tilde{c}_1, c_2)$ and $\tilde{c}_N = f(\tilde{c}_1, \tilde{c}_2)$. Let firm S's marginal production cost be c_S^α, $\tilde{c}_S$, and $\tilde{c}_S^\alpha$ under strategies (i), (ii), and (iii), respectively. Hence, we have $c_S^\alpha = f(\alpha\tilde{c}_1, c_2)$, $\tilde{c}_S = f(c_1, \tilde{c}_2)$, and $\tilde{c}_S^\alpha = f(\alpha\tilde{c}_1, \tilde{c}_2)$. As $\alpha\tilde{c}_i < c_i$ $(i = 1, 2)$, we then have $\tilde{c}_S^\alpha < \tilde{c}_S$. To reflect the fact that the marginal production cost under pure innovation is lower than that under pure imitation we assume that $\tilde{c}_S < c_S^\alpha$. Thus we have $\tilde{c}_S^\alpha < \tilde{c}_S < c_S^\alpha$. We denote the profit function of firm j by $\pi_j(\ ,\ )$ $(j = N, S)$, where the first (second) argument is the marginal cost of firm N (firm S).

We now proceed to a discussion of the behavior and payoff of the firms under different patent regimes.

3. Effects of Patent Regime

3.1 Weak Patent Protection

We first consider the case of weak patent protection in the developing country. Patent protection strength refers to the adequacy of the patent laws and regulations and enforcement mechanisms a country has in place. Stronger patent protection provides transparency and certainty for investors, licensees, and customers (Maskus 2004). In our context, weak patent protection means that firms pay lower imitation costs in both the absence and presence of a contractual relationship if there is an infringement of existing patents.

We solve the subgame perfect equilibrium through the usual method of backward induction. We begin by analyzing the case of successful licensing. In this case, firm S engages in R&D on component 2 and licenses it to firm N in stage 2. In principle, firm S

has two choices with regard to the component 1 technology: it can produce at $\tilde{c}_S$ without pirating firm N's technology or, alternatively, it can produce as efficiently as N by pirating that technology, as N has to reveal information on component 1 to S to facilitate the latter's innovation on component 2. In this event, firm S's production cost becomes $\tilde{c}_N$. By engaging in piracy, firm S also has to pay I_1 as an injunctive remedy. Alternatively, S can choose not to imitate under licensing. We assume that $I_1 < \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, and thus, in equilibrium, firm S chooses to pirate firm N's component 1 technology and produces at $\tilde{c}_N$. Hence, the production profits of N and S under a successful licensing arrangement are given by $\pi_N(\tilde{c}_N, \tilde{c}_N)$ and $\pi_S(\tilde{c}_N, \tilde{c}_N)$, respectively. Accordingly, their payoffs in this scenario are $\pi_N(\tilde{c}_N, \tilde{c}_N) - L$ and $\pi_N(\tilde{c}_N, \tilde{c}_N) + L - R_S$, respectively.

If firm N's licensing contract is rejected, it carries out in-house R&D on component 2, and firm S chooses one of the three options mentioned in Section 2.

In Table 1, we summarize the profits of the two firms in different scenarios.

		Profit of firm N	Profit of firm S
With contractual R&D		$\pi_N(\tilde{c}_N, \tilde{c}_N) - L$	$\pi_S(\tilde{c}_N, \tilde{c}_N) + L - R_S$
Without contractual R&D	Firm S chooses strategy (i)	$\pi_N(\tilde{c}_N, c_S^{\alpha}) - R_N$	$\pi_S(\tilde{c}_N, c_S^{\alpha}) - I_0$
	Firm S chooses strategy (ii)	$\pi_N(\tilde{c}_N, \tilde{c}_S) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$
	Firm S chooses strategy (iii)	$\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_S - I_0$

Table 1: Profits in Different Scenarios under Weak Patent Protection

The profit functions in the table show that a high component 2 R&D cost for firm N and a high degree of imitation capacity by firm S decrease the profit that N receives, whereas a high component 2 R&D cost, high component 1 imitation cost, and low degree of imitation capacity all decrease the profit received by S.

We assume that the imitation cost under weak patent protection is low, and thus that $I_0 < \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this event, strategy (ii) is dominated by strategy (iii). Licensing can occur only if the profit of each firm under licensing is greater than that under an outside option. Here, we discuss two cases.

If $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha})$, strategy (iii) dominates strategy (i) for firm S. Thus, the reservation values of successful licensing are payoffs under strategy (iii). As firm S's production profit under licensing is greater than its payoff under strategy (iii) ($\pi_S(\tilde{c}_N, \tilde{c}_N) - R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_S - I_0$), we have $L = 0$ because access to firm N's component 1 technology in these circumstances enhances S's production efficiency. We next analyze firm N's incentive on contractual R&D. By comparing the former's payoff under licensing and under strategy (iii), we find that successful licensing occurs when $R_N > \pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_N)$.

If $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha})$, strategy (i) dominates strategy (iii) for firm S. In this scenario, we have two cases. When $R_S < \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + I_0$, firm S's production profit under contractual R&D is greater than that under strategy (i). Thus, we have $L = 0$. When we compare firm N's payoff under licensing and under strategy (i), we find that successful licensing occurs when $R_N > \pi_N(\tilde{c}_N, c_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_N)$. When $R_S > \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + I_0$, firm S's production profit under contractual R&D is less

than that under strategy (i). Hence, we have $L = \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_N) + R_S$. Comparing firm N's payoff under licensing with that under strategy (i), we find that licensing occurs only when $\pi_N(\tilde{c}_N, \tilde{c}_N) + \pi_S(\tilde{c}_N, \tilde{c}_N) - R_S > \pi_N(\tilde{c}_N, c_S^\alpha) + \pi_N(\tilde{c}_N, c_S^\alpha) - R_N$. Marjit (1990)[15] shows that in a Cournot duopoly model, the industry profit increases if one of the firms is more efficient, as the two firms are reasonably close in terms of their initial technologies. Therefore, in this case, successful licensing always occurs.

Let a_1 and a_2 denote $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$ and $\pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^\alpha) + I_0$, respectively, and let b_1 and b_2 denote $\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_N)$ and $\pi_N(\tilde{c}_N, c_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_N)$, respectively. We have $a_1 < a_2$ and $b_1 < b_2$, which gives us the following lemma.

Lemma 1. *(1) Successful licensing occurs where the reservation values are payoffs under strategy (iii) for $R_S < a_1$ and $R_N > b_1$. (2) Successful licensing occurs where the reservation values are payoffs under strategy (i) for $a_1 < R_S < a_2$ and $R_N > b_2$. (3) Licensing always occurs for $R_S > a_2$.*

The economic intuition is as follows. When R_S is small ($R_S < a_2$), a large R_N reduces firm N's reservation value, which in turn increases its incentive to engage in licensing. When R_S is large ($R_S > a_2$), firm S's outside option is strategy (i) (imitating

[15] Let c_1 and c_2 denote the marginal production costs of firms 1 and 2, and assume that $c_1 < c_2$. As Marjit (1990) shows, the Cournot industry profit decreases with c_2 if $c_2 < \frac{a + 4c_1}{5}$. The economic intuition is that firm 1's profit loss can be compensated only by an increase in profit for firm 2 when the latter firm's initial market share is sufficiently large (and the technology gap between the two firms is sufficiently close).

the component 1 technology without undertaking R&D on component 2). The shift from strategy (i) to contractual R&D boosts the industry profit because firm S becomes more efficient. Hence, licensing always occurs in this scenario.

The conditions for successful licensing under weak patent protection give us the following lemma.

Lemma 2. *Under weak patent protection in the South, contractual R&D becomes more likely when firm S's R&D cost for component 2 is low, firm N's R&D cost for component 2 is high, and firm S has a low degree of imitation capacity.*

3.2 Strong Patent Protection

We now consider the case of strong patent protection, with the southern country providing adequate laws and regulations and enforcement mechanisms. In this case, firms have to pay higher imitation costs in the absence ($I_0 < I_0'$) of, and greater injunctive remedies ($I_1 < I_1'$) in the presence of, a contractual relationship if there is an infringement of existing patents. We first analyze a scenario in which firm N will always bring a law suit against firm S if S imitates N's process innovation on component 1.

When a country enjoys strong patent protection, the threat that N will file a lawsuit against S if it imitates N's component 1 technology under contractual R&D is a credible one. For simplicity, we assume that $I_1' > \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, and thus that the production profit that firm S gains from pirating that technology is less than that it gains from not doing so. Hence, in equilibrium, S undertakes contractual R&D on component 1 without imitating N's component 1 technology. Accordingly, the payoffs of firms N and

S when there is a successful licensing arrangement are given by $\pi_N(\tilde{c}_N, \tilde{c}_S) - L$ and $\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S + L$, respectively.[16] If firm S rejects the licensing contract offered by firm N, it chooses from among the three options mentioned in Section 2.

The profits of the two firms in different scenarios are summarized in Table 2.

		Profit of firm N	Profit of firm S
With contractual R&D		$\pi_N(\tilde{c}_N, \tilde{c}_S) - L$	$\pi_S(\tilde{c}_N, \tilde{c}_S) + L - R_S$
Without contractual R&D	Firm S chooses strategy (i)	$\pi_N(\tilde{c}_N, c_S^\alpha) - R_N$	$\pi_S(\tilde{c}_N, c_S^\alpha) - I_0'$
	Firm S chooses strategy (ii)	$\pi_N(\tilde{c}_N, \tilde{c}_S) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$
	Firm S chooses strategy (iii)	$\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - I_0'$

Table 2: Profits in Different Scenarios under Strong Patent Protection

We first consider the scenario in which strategy (iii) dominates strategy (ii) for $I_0' < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this scenario, we have two cases.

First, if $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, strategy (iii) dominates strategy (i) for firm S. Thus, this firm's reservation value from successful licensing is its payoff under strategy (iii), and we have $L = \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S) - I_0'$. When we compare firm N's payoff

[16] Our results would be essentially the same if we considered the possibility that firm S makes a commitment not to produce after a successful licensing arrangement is made in the presence of strong IPRs. In such circumstances, N would enjoy a monopoly in the market, and S would not produce in the third stage.

under licensing and under strategy (i), we find that successful licensing occurs when $R_N > \pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S) - I_0'$.

Second, if $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha})$, strategy (i) dominates strategy (iii) for firm S. When $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + I_0'$, S's production profit is greater under contractual R&D than under strategy (i). Thus, we have $L = 0$, and successful licensing occurs when $R_N > \pi_N(\tilde{c}_N, c_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S)$. When $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + I_0'$, we have $L = \pi_S(\tilde{c}_N, c_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S) + R_S - I_0'$, and licensing occurs only when $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) + R_N + I_0' > \pi_N(\tilde{c}_N, c_S^{\alpha}) + \pi_S(\tilde{c}_N, c_S^{\alpha}) + R_S$. As this condition always holds, successful licensing always occurs in this event.

We next consider the case in which strategy (ii) dominates strategy (iii) for $I_0' > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this case, firm S's production profit under contractual R&D is the same as its reservation value; therefore, $L = 0$, and licensing always occurs.

Let a_2' denote $\pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + I_0'$, and let b_1' and b_2' denote $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S) - I_0'$ and $\pi_N(\tilde{c}_N, c_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S)$, respectively. The equilibrium results in the presence of strong patent protection can be summarized as follows. (1) Successful licensing occurs where the reservation values are payoffs under strategy (iii) for $R_S < a_1$ and $R_N > b_1'$ and (2) where the reservation values are payoffs under strategy (i) for $a_1 < R_S < a_2'$ and $R_N > b_2'$, and (3) it always occurs for $R_S > a_2'$.

The difference between b_1' and b_1 is given by $b_1' - b_1 = \pi_N(\tilde{c}_N, \tilde{c}_N) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S) - I_0'$. Hence, we have $b_1' < b_1$ when

$\pi_N(\tilde{c}_N,\tilde{c}_N)+\pi_S(\tilde{c}_N,\tilde{c}_S^{\alpha})-\pi_N(\tilde{c}_N,\tilde{c}_S)-\pi_S(\tilde{c}_N,\tilde{c}_S)<I_0'$. We also have $b_2'-b_2=\pi_N(\tilde{c}_N,\tilde{c}_N)-\pi_N(\tilde{c}_N,\tilde{c}_S)<0$. Note that a lower $b_1'(b_1)$ and $b_2'(b_2)$ imply that contractual R&D is more likely. Thus, we find that contractual R&D occurs under strengthened patent protection, but not under weak patent protection, for (1) $R_S<a_1$ and $b_1<R_N<b_1'$ and (2) $a_1<R_S<a_2$ and $b_2'<R_N<b_2$, which gives us the following proposition.

Proposition 1. *Patent protection increases the two firms' incentives for R&D specialization when each firm has competitive advantage in R&D on one component and firm S has a low level of imitation capacity.*

The economic intuition is as follows. In the absence of patent protection, it can be profitable for a firm to imitate a competitor's technology due to the low imitation cost. Stronger patent protection thus reduces firms' incentives to imitate, as they face higher imitation cost. Accordingly, firm S has an incentive to shift from imitation to cooperative R&D. Poor imitation capacity also reduces firm S's reservation value and enhances its incentive to shift from imitator to innovator.

3.3 Strategic Enforcement

In this section, we discuss the possibility that firm N may choose strategic weak enforcement even though the southern government provides adequate laws and regulations, meaning that N may choose not to bring a law suit against firm S if it imitates N's component 1 technology.

To include firm N's strategic incentive for IPRs enforcement, the time sequence of the game is modified as follows. If N conducts in-house R&D or its R&D contract is rejected by S in stage 2, the game is the same as that described in Section 2. If S accepts the contract in stage 2, however, N must choose between strong and strategic weak enforcement in stage 3. Depending on the enforcement choice that N makes, S then chooses whether to imitate N's component 1 technology in stage 4, and the two firms compete on quantity in stage 5.

If firm N chooses strong enforcement, firm S will not imitate its technology under contractual R&D in the knowledge that N will file a lawsuit against it for patent infringement. The payoffs of firms N and S are given by $\pi_N(\tilde{c}_N, \tilde{c}_S) - L$ and $\pi_S(\tilde{c}_N, \tilde{c}_S) + L - R_S$, respectively. If N chooses strategic weak enforcement, however, S is permitted to imitate the former's component 1 technology even under contractual R&D, and the payoffs become $\pi_N(\tilde{c}_N, \tilde{c}_N) - L$ and $\pi_S(\tilde{c}_N, \tilde{c}_N) + L - R_S$.

As firm S's production profit under strategic weak enforcement is higher than that under strong enforcement, firm S chooses to imitate firm N's component 1 technology under strategic weak enforcement. Note that the industry profit increases, as one of the firms is more efficient. As $\tilde{c}_N < \tilde{c}_S$, we find that the joint industry profit is greater under strategic weak IPR enforcement than under strong enforcement ($\pi_N(\tilde{c}_N, \tilde{c}_N) + \pi_S(\tilde{c}_N, \tilde{c}_N) - R_S > \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$). As N offers a take-it-or-leave-it contract to S, however, it extracts all of the increase in that profit, with S receiving only its reservation value. Thus, firm N is likely to be better off under strategic weak IPR enforcement than under strong enforcement.

In the absence of a successful R&D contract, the profit functions are the same under

strategic weak and strong enforcement. The profits of the two firms N in different scenarios are summarized in Table 3.

		Profit of firm N	Profit of firm S
With contractual R&D		$\pi_N(\tilde{c}_N, \tilde{c}_N) - L$	$\pi_S(\tilde{c}_N, \tilde{c}_N) + L - R_S$
Without contractual R&D	Firm S chooses strategy (i)	$\pi_N(\tilde{c}_N, c_S^\alpha) - R_N$	$\pi_S(\tilde{c}_N, c_S^\alpha) - I_0'$
	Firm S chooses strategy (ii)	$\pi_N(\tilde{c}_N, \tilde{c}_S) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$
	Firm S chooses strategy (iii)	$\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N$	$\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - I_0'$

Table 3: Profits in Different Scenarios under Strategic Patent Protection

We first consider the scenario in which strategy (iii) dominates strategy (ii) for $I_0' < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this scenario, we have two cases.

First, if $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, strategy (iii) dominates strategy (i) for firm S. Thus, S's reservation value from successful licensing is its payoff under strategy (iii). In this case, we have $L = 0$, and successful licensing always occurs.

Second, if $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, strategy (i) dominates strategy (iii) for firm S. When $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha) < R_S < \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^\alpha) + I_0'$, we have $L = 0$, and successful licensing occurs if $R_N > \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_N)$. When $R_S > \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^\alpha) + I_0'$, firm S's production profit under licensing is less than its payoff under strategy (iii). Hence, we have $L = \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_N) + R_S - I_0'$, and licensing

occurs only when $\pi_N(\tilde{c}_N,\tilde{c}_N)+\pi_S(\tilde{c}_N,\tilde{c}_N)-R_S>\pi_N(\tilde{c}_N,c_S^{\alpha})+\pi_S(\tilde{c}_N,c_S^{\alpha})-R_N-I_0'$. As this condition always holds, contractual R&D always occurs.

We next consider the case in which strategy (ii) dominates strategy (iii) for $I_0'>\pi_S(\tilde{c}_N,\tilde{c}_S^{\alpha})-\pi_S(\tilde{c}_N,\tilde{c}_S)$. In this case, $L=0$, and successful licensing always occurs.

Let a_3 denote $\pi_S(\tilde{c}_N,\tilde{c}_N)-\pi_S(\tilde{c}_N,c_S^{\alpha})+I_0'$. The equilibrium results under strategic weak enforcement can be summarized as follows. (1) Contractual R&D always occurs for $R_S<a_1$ where the reservation values are the payoffs of strategy (iii). (2) Contractual R&D occurs for $a_1<R_S<a_3$ and $R_N>b_2$ where the reservation values are the payoffs of strategy (i). (3) Contractual R&D always occurs for $R_S>a_3$ where the reservation values are the payoffs of strategy (i).

Comparing the equilibrium results with strategic weak enforcement and those with strong enforcement shows that contractual R&D will not occur under strong IPRs enforcement, but will occur under strategic weak enforcement for $R_N<b_1'$ and $R_S<a_1$. Hence, contractual R&D becomes more likely when the option of strategic weak enforcement is allowed, which gives rise to the following proposition.

Proposition 2. *Firm N's strategic behavior in choosing weak IPRs enforcement can increase the probability of contractual R&D in developing countries.*

The intuition is as follows. When the difference in the component 2 R&D cost between firms N and S is small ($R_S<R_N<b_1'$), and N chooses strong patent protection, S has no incentive to switch from imitation to contractual R&D because the total benefit

conferred by such R&D is insufficiently large to cover S's loss from the switch. When strategic weak enforcement becomes an option, however, firm S is able to produce more efficiently by imitating firm N's component 1 technology under a contractual R&D arrangement, which in turn increases the total industry profit. In these circumstances, the total benefit induced by contractual R&D is sufficient to cover the loss firm S suffers from the switch, rendering contractual R&D more likely. Hence, the increase in total industry profit resulting from strategic weak enforcement can serve as a subsidy for S's switch from pure imitation to contractual R&D. We refer to this as the "subsidizing effect" of strategic weak enforcement.

We illustrate the equilibrium results in different circumstances in Figures 1, 2, and 3, in which the horizontal and vertical axes represent the component 2 R&D costs of firms S and N, respectively. The shaded area in regions I, II, and III of Figure 1 represent the equilibrium when contractual R&D occurs under weak patent protection. Note that firm N's component 2 R&D cost is greater than firm S's. Under strong patent protection, the equilibrium for contractual R&D's occurrence corresponds with the shaded area in Figure 2. Finally, in the event of strategic weak enforcement, the equilibrium for contractual R&D's occurrence corresponds with the shaded area in Figure 3.

3.4 A Note on Cross-licensing

In principle, firm N could also license the component 1 technology to firm S. Although such an arrangement is often not feasible in the real world because northern firms tend to protect their core technologies from leakage, we here discuss how our results would

change if we permitted this possibility.[17] Cross-licensing occurs when firm S licenses component 2 technology to firm N, and N licenses component 1 technology to S. Comparison of the equilibrium results under different scenarios shows that when the South shifts from weak to strong patent protection, the incentives to engage in contractual R&D under a cross-licensing arrangement increase further, thus strengthening our conclusions. Given that the southern country in question offers adequate laws and regulations, a northern firm has no incentive to implement strategic weak enforcement under a cross-licensing arrangement because both firms' profits under contractual R&D are the same in both events.

4. Welfare Effects of IPRs Policy

It is also of interest to evaluate the effects of changes in the patent regime on southern welfare, which is defined as the sum of the local consumer surplus and firm S's profit. As the detailed calculations are complex, to save space we simply provide an overview of the results here (see Appendix B for the mathematical derivations).

4.1 Welfare Effects of Strengthened IPRs

We first discuss the change in southern welfare resulting from a shift from weak to strong patent protection. The results show that in this event, the consumer surplus in the southern country increases, and firm S's profit decreases. The economic intuition is as follows. First, such a policy shift encourages contractual R&D, which in turn increases the productivity of firm S and expands consumption in the southern market. Second, the increase in imitation cost decreases S's profit under imitation, thereby decreasing its

[17] These results are mathematically demonstrated in Appendix A.

reservation value. Accordingly, the strengthened IPRs regime also decreases S's profit under contractual R&D. The consumer gain owing to an increase in firm S's productivity grows larger with an increase in the costs saved by shifting from imitation to contractual R&D. Further, as firm S's bargaining strength increases, both S's profit and southern welfare are enhanced. In brief, strong patent protection boosts local welfare when there is a large degree of cost-savings from contractual R&D and southern firms enjoy a relatively strong bargaining position. It may diminish southern welfare otherwise.

4.2 Welfare Effects of Strategic Enforcement

For $R_S < a_1$ and $R_N < b_1'$, the equilibrium regime is strategy (iii) under strong enforcement, and contractual R&D under strategic weak enforcement. As shown in Appendix B, upon reaching the licensing equilibrium range, the Southern consumer surplus increases owing to an increase in firm S's productivity. The policy change also allows S to imitate without incurring an imitation cost under contractual R&D, thereby boosting S's profit. Accordingly, southern welfare rises due to the increase in both southern consumer surplus and firm S's profit.

5. Adding Offshore R&D Subsidiary

Thus far, we have analyzed a multinational firm's choice between undertaking in-house R&D and outsourcing R&D to a local firm in a developing country. An alternative organizational choice would be for the multinational firm to establish a wholly owned R&D subsidiary in that country. Setting up R&D subsidiaries in developing countries allows multinational firms to take advantage of the lower R&D costs in those countries.

To capture this feature, we now incorporate a simple specification of an R&D subsidiary into our model.

Suppose that firm N has the option of establishing an R&D subsidiary in the South. Following Antràs and Helpman (2004), we assume that the fixed organizational cost of integration abroad (setting up an R&D subsidiary) is greater than that of outsourcing (conducting contractual R&D). To simplify our analysis, we further assume that set-up cost g is incurred by integration (setting up an R&D subsidiary), whereas no such cost is incurred by outsourcing. We also assume that the component 2 R&D cost for the southern subsidiary is R_S, which is the same as that for firm S undertaking contractual R&D, demonstrating that the southern subsidiary can also take advantage of the lower R&D costs in developing countries. As a result, the cost difference between conducting R&D through an R&D subsidiary and through outsourcing is set-up cost g.

In this scenario, firm N has two outside options: conducting in-house R&D in the North and setting up an R&D subsidiary in the South. Firm S has the three outside options set out in previous sections. Working through the payoff functions, we obtain the following results.[20] If the subsidiary set-up costs are large and patent protection is weak, in equilibrium firm N conducts in-house R&D. In this event, the large set-up costs will discourage N from opting for establishment of an R&D subsidiary. As the South strengthens its patent protection, the equilibrium shifts from integration at home (conducting in-house R&D in the North) to outsourcing (undertaking contractual R&D). If the subsidiary set-up cost is sufficiently small and patent protection is weak, in equilibrium firm N will choose to carry out R&D via an R&D subsidiary. Strengthened

[20] See Appendix C for the proof.

patent protection shifts the equilibrium from integration abroad (establishing an R&D subsidiary) to outsourcing (undertaking contractual R&D) in this event.

The economic intuition for this result is as follows. When the set-up cost of establishing an R&D subsidiary is sufficiently small, firm N's reservation value is large. Therefore, N may choose to establish an R&D subsidiary rather than engage in contractual R&D when the patent protection regime is weak. When that regime is strengthened, firm S has no incentive to imitate firm N's component 1 technology because it believes that N might bring a lawsuit against it if it engages in imitation under a contractual R&D arrangement. Hence, firm N's profit under such an arrangement is increased, rendering contractual R&D more likely.

In essence, the foregoing results can be characterized as follows. In developing countries in which the subsidiary set-up costs are large and patent protection is weak, a multinational will choose to conduct in-house R&D in the North. Strong patent protection encourages contractual R&D. However, a southern country with weak patent protection can attract an R&D subsidiary by reducing the subsidiary set-up cost. For example, the southern government could improve infrastructure by constructing industrial facilities and/or offer FDI subsidies, job-creation subsidies, and tax cuts.

6. Concluding Remarks

This paper offers a new perspective on IPRs protection in developing countries. Our analysis yields several interesting results. First, by reducing a southern firm's profits from engaging in imitation, strong IPRs increase that firm's incentive to undertake contractual R&D, thereby encouraging international specialization in R&D. Second, a multinational

firm's strategic IPRs enforcement may encourage contractual R&D. Third, we find that southern welfare can rise when strong IPRs are accompanied by large cost-savings from innovation and southern firms enjoy a relatively strong bargaining position. Finally, we show how a policy mix of IPRs and FDI subsidies in developing countries affects R&D activities by adding an offshore R&D subsidiary as an alternative organizational form.

Our analysis can be extended to more general environments. We have assumed that a southern firm can license its technology on one component of a product to only one northern firm. However, in the real world, it is possible for a southern firm to license its technology to multiple northern firms producing differentiated goods but using the technology as just one component. If we allow this possibility, firm S's bargaining power strengthens because of the large number of potential buyers. Hence, the firm has more incentives to undertake contractual R&D, and our conclusions are strengthened.

Another promising avenue for future research would be to examine the effects of a policy mix of an R&D subsidy and IPRs on contractual R&D. Strengthening an IPRs policy could alter domestic firms' incentives to engage in contractual R&D, which in turn could affect the R&D subsidy policy. Such analysis would be of great interest to developing countries, as R&D subsidy policies play a vital role in shaping domestic innovation capacities.

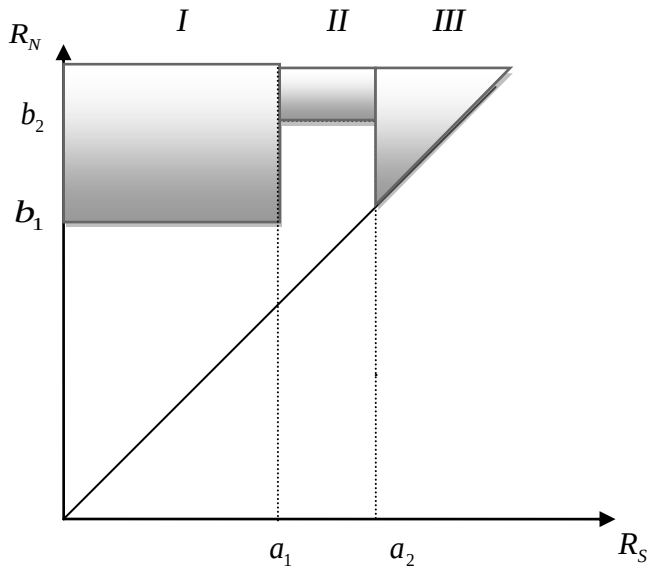

Figure 1. Equilibrium Results under Weak Patent Protection

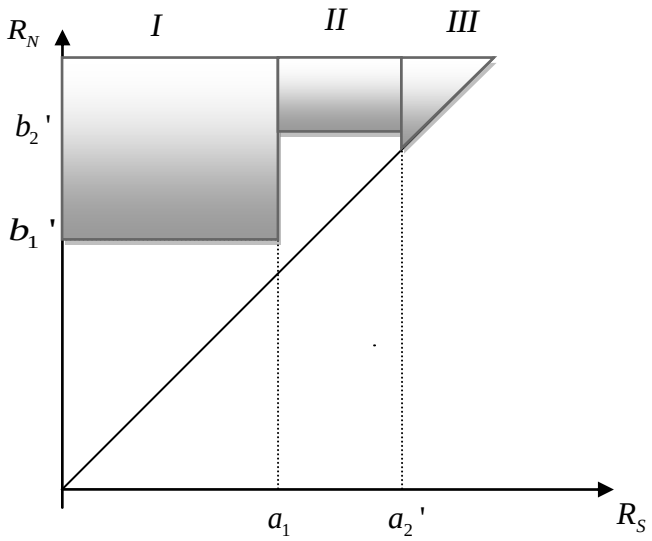

Figure 2. Equilibrium Results under Strong Patent Protection

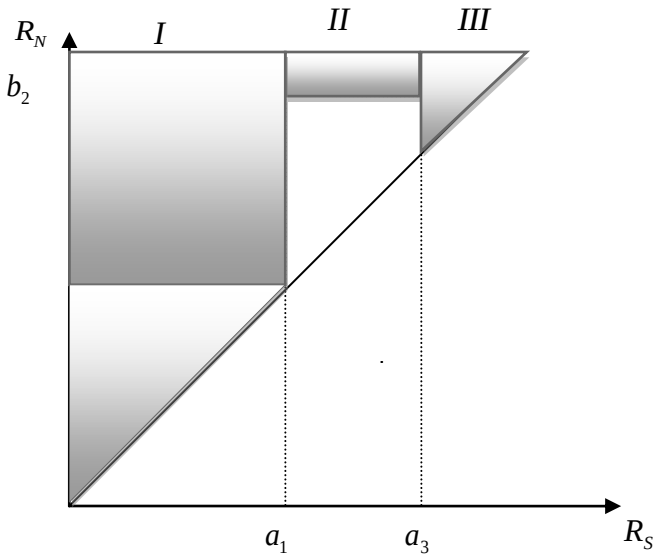

Figure 3. Equilibrium Results under Strategic Weak Enforcement

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Appendix A: The Results with Cross-licensing

Cross-licensing occurs when firm S licenses its component 2 technology to firm N, and firm N licenses its component 1 technology to firm S. Let L_1 and L_2 denote the licensing fees of the component 1 and component 2 technologies, respectively, under cross-licensing.[21] Hence, the profits of firms N and S under cross-licensing are given by $\pi_N(\tilde{c}_N, \tilde{c}_N) - L_2 + L_1$ and $\pi_S(\tilde{c}_N, \tilde{c}_N) + L_2 - L_1 - R_S$, respectively. Their profits without contractual R&D are the same as those in Table 1.

Under weak patent protection, firm S produces at $\tilde{c}_N$ by choosing imitation under a single licensing arrangement. Thus, it has no incentive to pay a licensing fee to firm N to obtain the component 1 technology. Hence, we have $L_1 = 0$, and the profits of both firms are the same as those under single licensing when the option of cross-licensing is introduced.

We next demonstrate the equilibrium results under strong patent protection. We first consider a scenario in which strategy (iii) dominates strategy (ii) for $I_0' < \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this scenario, we have two cases. First, if $R_S < \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha})$, strategy (iii) dominates strategy (i) for firm S. Thus, firm S's reservation value of successful licensing is its payoff under strategy (iii), and we have $L_2 - L_1 = \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_N) - I_0'$. Hence, we find that successful licensing occurs when $R_N > \pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, \tilde{c}_N) - I_0'$. As $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, \tilde{c}_N) - I_0' < 0$, licensing always occurs in this case. If $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha})$, there are two possibilities.

[21] To simplify the analysis, we assume that cross-licensing occurs only under contractual R&D.

When $R_S < \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^\alpha) + I_0'$, we have $L_2 - L_1 = 0$, and successful licensing occurs if $R_N > \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_N)$. When $R_S > \pi_S(\tilde{c}_N, \tilde{c}_N) - \pi_S(\tilde{c}_N, c_S^\alpha) + I_0'$, firm S's production profit under licensing is less than its payoff under strategy (iii). Hence, $L_2 - L_1 = \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_N) + R_S - I_0'$, and licensing alone occurs. Second, if $R_S > \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, strategy (i) dominates strategy (iii) for firm S. Hence, we have $L_2 - L_1 = \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_N) + R_S - I_0'$, and licensing occurs when $\pi_N(\tilde{c}_N, \tilde{c}_N) + \pi_S(\tilde{c}_N, \tilde{c}_N) + R_N + I_0' > \pi_N(\tilde{c}_N, c_S^\alpha) + \pi_S(\tilde{c}_N, c_S^\alpha) + R_S$. As this condition always holds, successful licensing always occurs in this case. We next consider the case in which strategy (ii) dominates strategy (iii) for $I_0' > \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this case, firm S's production profit under contractual R&D is the same as its reservation value; therefore, $L_2 - L_1 = 0$, and licensing always occurs.

The equilibrium results with both cross-licensing and strong patent protection can be summarized as follows. (1) Successful licensing always occurs when the reservation values are payoffs under strategy (iii) for $R_S < a_1$. (2) Contractual R&D occurs for $a_1 < R_S < a_3$ and $R_N > b_2$ when the reservation values are the payoffs of strategy (i). (3) Contractual R&D always occurs for $R_S > a_3$ when the reservation values are payoffs of strategy (i). These results show that when a southern country shifts from weak to strong patent protection, with the option of cross-licensing, the incentives for undertaking contractual R&D are further increased, and our conclusions are strengthened.

When cross-licensing exists, firm S will not imitate firm N's component 1 technology under contractual R&D because it has obtained that technology through

cross-licensing. Therefore, strategic weak enforcement will occur only under single licensing. Comparing the equilibrium results for cross-licensing and strong patent protection with those for single licensing and strategic enforcement, we find that firm N has no incentive to adopt strategic weak enforcement because both firms' profits under contractual R&D are the same in both events.

Appendix B: Southern Welfare

To illustrate the effects of patent protection on southern welfare, we assume that the inverse-demand function for our product in the South is given by $P = a - q$, where a represents the market size of the South, P is the price of the product, and q is the quantity produced. The welfare of the southern country is the sum of the southern consumer surplus and firm S's profit. Let q_N and q_S denote the output of firms N and S in the southern country, respectively. Let CS and W_S represent the southern consumer surplus and southern welfare, respectively. We then have $CS = \frac{(q_S + q_N)^2}{2}$ [22] and $W_S = CS + \pi_S = \frac{(q_S + q_N)^2}{2} + \pi_S$.[23]

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[22] Suppose that the inverse-demand function is $p = a - q$. Let c_1 and c_2 denote the marginal production costs of firms 1 and 2. Let q_1 and q_2 denote the two firms' equilibrium output in a Cournot competition. The market equilibrium price is given by $p^* = a - (q_1 + q_2)$, and the consumer surplus is given by $\int_0^{q_1+q_2} (p - p^*)dq = \int_0^{q_1+q_2} [(a-q) - (a - q_1 - q_2)]dq = \int_0^{q_1+q_2} (q_1 + q_2 - q)dq = \frac{(q_1 + q_2)^2}{2}$.

[23] Given the general assumptions made about Cournot competition in footnote 19, the equilibrium outputs of firms 1 and 2 are given by $q_1 = \frac{a + c_2 - 2c_1}{3}$ and $q_2 = \frac{a + c_1 - 2c_2}{3}$. Let π_1 and π_2 denote the equilibrium production profits of the two firms. Then, we have $\pi_1 = (a - q_1 - q_2)q_1 - c_1 q_1 = {q_1}^2$. Similarly, $\pi_2 = {q_2}^2$.

B.1 Change in Southern Welfare with a Shift from Weak to Strengthened Patent Protection

As discussed in Section 3.2, contractual R&D will occur under strengthened patent protection, but not under weak patent protection for (1) $R_S < a_1$ and $b_1 < R_N < b_1'$ or (2) $a_1 < R_S < a_2$ and $b_2' < R_N < b_2$. Here, we discuss these two cases separately.

For $R_S < a_1$ and $b_1 < R_N < b_1'$, strategy (iii) is the equilibrium under weak patent protection. Hence, the marginal production costs of firms N and S are $\tilde{c}_N$ and $\tilde{c}_S^{\alpha}$, respectively, and we therefore have $q_N = \frac{a + \tilde{c}_S^{\alpha} - 2\tilde{c}_N}{3}$ and $q_S = \frac{a + \tilde{c}_N - 2\tilde{c}_S^{\alpha}}{3}$. We also have $CS = \frac{(q_S + q_N)^2}{2} = \frac{(2a - \tilde{c}_N - \tilde{c}_S^{\alpha})^2}{18}$ and $\pi_S = {q_S}^2 = \frac{(a + \tilde{c}_N - 2\tilde{c}_S^{\alpha})^2}{9} - R_S - I_0$. Accordingly, southern welfare is given by $\frac{(2a - \tilde{c}_N - \tilde{c}_S^{\alpha})^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S^{\alpha})^2}{9} - R_S - I_0$.

Under strengthened patent protection, contractual R&D will occur, and we thus have $q_N = \frac{a + \tilde{c}_S - 2\tilde{c}_N}{3}$, $q_S = \frac{a + \tilde{c}_N - 2\tilde{c}_S}{3}$, $CS = \frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18}$, and $\pi_S = \frac{(a + \tilde{c}_N - 2\tilde{c}_S)^2}{9} - R_S$, and southern welfare is given by $\frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S)^2}{9} - R_S$. As firm N offers a take-it-or-leave-it contract to firm S, the latter's profit under licensing is equivalent to its profit under strategy (iii). Hence, southern welfare can also be written as $\frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S^{\alpha})^2}{9} - R_S - I_0'$. Accordingly, the consumer surplus in the southern market increases, and firm S's profit decreases, with a change in policy from weak to strengthened patent protection.

For $a_1 < R_S < a_2$ and $R_N < b_2$, strategy (i) is the equilibrium under weak patent protection. Hence, we have $q_N = \frac{a + c_S^{\alpha} - 2\tilde{c}_N}{3}$ and $q_S = \frac{a + \tilde{c}_N - 2c_S^{\alpha}}{3}$. Southern welfare is given by $\frac{(2a - \tilde{c}_N - c_S^{\alpha})^2}{18} + \frac{(a + \tilde{c}_N - 2c_S^{\alpha})^2}{9} - I_0$. Under strengthened patent protection, southern welfare becomes $\frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S)^2}{9} - R_S$ with successful licensing. As firm S's profit under licensing is equivalent to its profit under strategy (i), southern welfare can also be written as $\frac{(2a - \tilde{c}_N - c_S^{\alpha})^2}{18} + \frac{(a + \tilde{c}_N - 2c_S^{\alpha})^2}{9} - I_0'$. Similarly, we find the consumer surplus in the southern country to increase, and firm S's profit to decrease with a change in policy from weak to strengthened patent protection.

B.2 Change in Southern Welfare with a Shift from Strong to Strategic Weak Enforcement

In this section, we focus on the case in which a change in policy from strong to strategic weak enforcement changes the equilibrium from no contractual R&D to contractual R&D.

As discussed in Section 5, for $R_S < a_1$ and $R_N < b_1'$, strategy (iii) is the equilibrium under weak patent protection. Hence, southern welfare is given by $\frac{(2a - \tilde{c}_N - \tilde{c}_S^{\alpha})^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S^{\alpha})^2}{9} - R_S - I_0'$. Under strengthened patent protection, the equilibrium changes to contractual R&D, and thus southern welfare changes to $\frac{(2a - 2\tilde{c}_N)^2}{18} + \frac{(a - \tilde{c}_N)^2}{9} - R_S$. In this scenario, both the consumer surplus in the southern

country and firm S's profit increase with a change in policy from strong to strategic weak enforcement.

Appendix C: Equilibrium Results with an R&D Subsidiary

We first consider the case in which the set-up cost of an R&D subsidiary is sufficiently large ($g > R_N - R_S$). In this event, firm N's profit from conducting in-house R&D in the north is greater than that from establishing an R&D subsidiary. As a result, the equilibrium results are the same as those discussed above. Under weak patent protection, firm N conducts in-house R&D. As southern countries strengthen their patent protection, the equilibrium may shift from integration at home (conducting in-house R&D in the North) to outsourcing (undertaking contractual R&D).

We next consider the case in which the set-up cost of an R&D subsidiary is sufficiently small ($g < R_N - R_S$). In this case, firm N's profit from in-house R&D in the north is less than that from establishing an R&D subsidiary. Firm N's outside option is setting up an R&D subsidiary in the South, whereas firm S has the three outside options set out in previous sections in the case of a breakdown in contractual R&D negotiations.

We first discuss the weak patent protection case. The two firms' profits in different scenarios are summarized in Table C1. If $R_S < a_1$, strategy (iii) dominates strategy (i) for firm S. Hence, we have $L = 0$, and licensing occurs only when $g > -R_S + b_1$. If $a_1 < R_S < a_2$, strategy (i) dominates strategy (iii) for S. As S's production profit is greater under contractual R&D than under strategy (i), we find that $L = 0$, and successful licensing occurs when $R_S > b_2 - g$. If $R_S > a_2$, strategy (i) dominates strategy (iii). We

find that firm S's production profit under contractual R&D is less than that under strategy (i), and licensing always occurs.

		Profit of firm N	Profit of firm S
With contractual R&D		$\pi_N(\tilde{c}_N, \tilde{c}_N) - L$	$\pi_S(\tilde{c}_N, \tilde{c}_N) + L - R_S$
Without contractual R&D	Firm S chooses strategy (i)	$\pi_N(\tilde{c}_N, c_S^\alpha) - R_S - g$	$\pi_S(\tilde{c}_N, c_S^\alpha) - I_0$
	Firm S chooses strategy (ii)	$\pi_N(\tilde{c}_N, \tilde{c}_S) - R_S - g$	$\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$
	Firm S chooses strategy (iii)	$\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - g$	$\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - I_0$

Table C1: Profits with a R&D Subsidiary in Different Scenarios under Weak Patent Protection

Under strengthened patent protection the profits of firms N and S are summarized in Table C2. We obtain the following findings. If $R_S < a_1$, strategy (iii) dominates strategy (i) for firm S, and licensing occurs only when $b_1' - g < R_S < a_1$. If $a_1 < R_S < a_2'$, contractual R&D occurs when $R_S > b_2' - g$. If $R_S > a_2'$, strategy (i) dominates strategy (iii) for firm S, and licensing always occurs.

		Profit of firm N	Profit of firm S
With contractual R&D		$\pi_N(\tilde{c}_N, \tilde{c}_S) - L$	$\pi_S(\tilde{c}_N, \tilde{c}_S) + L - R_S$
Without contractual R&D	Firm S chooses strategy (i)	$\pi_N(\tilde{c}_N, c_S^{\alpha}) - R_S - g$	$\pi_S(\tilde{c}_N, c_S^{\alpha}) - I_0'$
	Firm S chooses strategy (ii)	$\pi_N(\tilde{c}_N, \tilde{c}_S) - R_S - g$	$\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$
	Firm S chooses strategy (iii)	$\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_S - g$	$\pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_S - I_0'$

Table C2: Profits with an R&D Subsidiary in Different Scenarios under Strong Patent Protection

Thus, firm N chooses to conduct R&D via an R&D subsidiary under weak patent protection, but switches to contractual R&D under strong patent protection for (1) $R_S < a_1$ and $b_1' - g < R_S < b_1 - g$; (2) $a_1 < R_S < a_2$, $a_1 < R_S < a_2$ and $b_2' - g < R_S < b_2 - g$. In these circumstances, strengthened patent protection shifts the equilibrium from integration abroad (setting up an R&D subsidiary) to outsourcing (undertaking contractual R&D).