Offshore Outsourcing, Contractual RD and Intellectual Property in Developing Countries

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Abstract

This paper examines the role of intellectual property in developing countries in offshore outsourcing of R&D. We find that strengthened intellectual property protection in developing countries provides incentive for firms, both multinational and local, to specialize in undertaking an R&D activity in which it has competitive advantage (*the specialization effect*). It also facilitates the process for local firms to switch from imitators to potential innovators (*the switching effect*). We demonstrate that the multinational firm's strategic behavior on IPR enforcement can be used as an effective instrument to subsidize contractual research and development in developing countries (*the subsidizing effect*). We further illustrate how a policy mix of IPR and FDI subsidy in developing countries affects R&D activities adding an offshore R&D subsidiary as an additional organizational form.

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1 Introduction

We are living in an age of outsourcing (Grossman and Helpman 2005). The ongoing process of outsourcing has even gone global by taking the form of offshore outsourcing — the relocation of business functions to an offshore provider external to the firm. Recently, offshore outsourcing is no longer limited to what firms perceive as non-core functions such as customer call centers or billing/collections; firms are now outsourcing key tasks such as research and development (R&D) to offshore providers through contractual R&D.

There is considerable evidence of this new trend in a variety of industries. In the pharmaceutical industry, the largest multinational pharmaceutical firms, including Merck, Eli Lilly, and Johnson & Johnson, first moved manufacturing and clinical-trial work to China and India. And now, driven by cost pressures and growth opportunities, they are partnering with firms there to do sophisticated drug research and clinical testing (Wadhwa 2008a). Indian companies such as Ranbaxy, Advinus Therapeutics, Nicholas Piramal and Jubilant have negotiated long-term deals with western pharmaceutical companies to discover and develop new chemical entities. A Chinese company, Hutchison MediPharma, has formed a similar partnership with Eli Lilly (Wadhwa 2008b). There is also a fast expansion of offshore outsourcing of R&D in the information technology (IT) industry. A lot of multinational IT firms, like Dell, Motorola and Philips are buying not only cell phones but also complete designs of some digital services from Asian developers. The R&D outsourcing market for information technology in India is projected to grow to more than $9 billion by 2010 from $1.3 billion in 2003, according to a study conducted by a business consulting firm Frost & Sullivan (Frost & Sullivan 2004). 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 its upcoming 7E7 Dreamliner jet (Engardio and Einhorn 2005).

At the macro level, data on licensing payments also show the boost of contractual R&D between multinational firms and local firms in developing countries. For example, U.S. licensing payments to Chinese firms rose from $1 million in 1995 to $13 million in 2000, reaching $115 million in 2007. U.S. licensing payments to Indian firms rose from $2 million in 2000 to $98 million in 2007.[1] China's official balance of payment statistics show that the licensing fee payments received by Chinese firms have registered a substantial increase, from US$82 million in 2000 to US$343 million in 2007. This highlights the fact that developing countries such as China and India have been increasingly engaged in the vertical specialization of global R&D activities.

There are several reasons for the proliferation of international specialization in R&D activities. [2] First, several developing countries, for example, India, China, and Brazil, have succeeded in building up research and development capacity in recent years, thereby reducing the technology gap between developed countries and developing countries. Second, research and development in some industries, for example, the pharmaceutical industry, is highly complex and prohibitively expensive. With intensifying globalization, multinational firms are under pressure to reduce the costs involved in R&D. Factors like lower labor cost, time saving due to the time zone difference between some developed countries and developing countries, higher patient enrolment rates as well as the prevalence of a wide variety of diseases and a heteroge-

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

[2]Ernst (2005) attributes internationalization of innovation to the following: (1) institutional change through liberalization; (2) the impact of information and communication technology; (3) market competition and organizational change; adjustments in corporate strategy and business models.

neous gene pool all contribute to the cost advantage in the drug research process.[3] As a result, the strategy of multinational firms is to specialize in a particular component of the R&D chain by which cost reduction in R&D could be achieved.

The offshore outsourcing of R&D presents fresh opportunities for developing countries in promoting their R&D activities, yet it creates new challenges to their intellectual property right (IPR) policy. While multinational firms (MNEs) find it profitable in the short term by engaging in offshore outsourcing of R&D, there are growing concerns about the loss of core proprietary business knowledge and intellectual property. In particular, offshore outsourcing is vulnerable to high turnover rates which create potential problems relating to sharing company trade secrets with a new employer and competitor (Hemphill 2005). Moreover, potential subcontractors in developing countries might find it more profitable by undertaking imitation instead of subcontracting. Under these circumstances, what is the role of intellectual property in affecting MNEs' incentive to outsource R&D as well as local firms' incentive to switch from an imitator to a R&D subcontractor? How should developing countries reform their IPR policy to be more conducive to their R&D activities in the age of globalization of R&D?

Previous research has addressed the question of whether developing countries can benefit from protecting intellectual property. It has been argued that strengthening intellectual property was not in the interest of developing countries as stronger intellectual property leads to an increase in the imitation cost of the Southern firms

[3]For example, bringing a new molecule to the market in the pharmaceutical industry was estimated at about $800 million in 2005, out of which a significant portion was spent on testing the drug on patients prior to commercial approval. A recent McKinsey study has suggested that cost saving in the drug research process is about $200 million if clinical trials are carried out in India. See "The HINDU survey of Indian Industry 2004" available at http://www.thehindu.com.

(Chin and Grossman 1990), reduction of consumer surplus due to monopoly pricing (Deardorff 1992), diminishing in both the long-run Northern rate of innovation and Southern welfare (Helpman 1993) .

Recently, economists began to realize that developing countries could benefit from stronger IPR in several aspects. Maskus and Penubarti(1995), Maskus (2000), Yang and Maskus (2001) and Chen and Puttitanun (2005) are the recent studies focusing on how stronger IPR could encourage inward flows of technology, a faster ability to close this gap in technological sophistication between themselves and rich countries and a flowering of local innovation. For instance, Yang and Maskus (2001) demonstrate that stronger IPR could increase long-run technology transfer and innovation if the mode of transfer is licensing as stronger IPR reduces the costs of such transfers relative to imitation costs and increases the licensor's share of production rents.

Another strand of the literature analyzes the impacts of intellectual property protection on R&D incentives and technology transfer in the presence of "tournament effect". Chowdhury (2005) argues that if patent protection makes the R&D competition into tournament, it reduces R&D investment if the tournament effect is negative. Mukherjee (2006) shows that the effect of either imitation or technology licensing may always dominate the tournament effect and create higher R&D investment under patent protection.[4]

The above literature, however, has not touched on the impacts of stronger intellectual property in developing countries on the contractual R&D activities which have proliferated in recent years. Our paper fills this void by offering a new perspective on the protection of IPRs in developing countries and establishing a link between

[4]In a related paper, Mukherjee and Pennings (2004) discuss the relationship between the choice of technology adoption and patent protection when an incumbent faces the threat of imitation from an entrant.

intellectual property and offshore outsourcing of R&D.

We consider a model where two firms in a developing country, one multinational and one local, produce a product composed of two components. The multinational firm and the local firm have competitive advantage in conducting R&D on component 1 and component 2 respectively. The multinational firm always undertakes R&D on component 1 due to its competitive advantage. The local firm, however, can either undertake R&D on component 2 and license it to the multinational firm as a subcontractor or imitate the multinational firm's technology on component 1 as an imitator, depending on the intellectual property protection in developing countries. In a three-stage game where the choice of the local firm as a subcontractor or imitator is determined in the first stage and two firms engage in process R&D or imitation in the second stage and then Cournot competition in the third stage, we find the following results.

First, we demonstrate that strong IPR in developing countries may induce firms, both multinational and local, to specialize in one stage of R&D, a "*specialization effect*" attributed to strong IPR. Second, we consider the possibility that an original imitator in developing countries may not be an imitator forever. Instead, it could eventually become a potential innovator. We show that there is a "*switching effect*" due to strong IPR. Third, in contrast to the conventional wisdom, our paper suggests that multinational firm's strategic behavior on IPR enforcement can be used as an effective instrument to subsidize contractual research and development in developing countries, which is beneficial to both local firms and multinational firms (*the subsidizing effect*). Fourth, we find that the welfare of developing countries could rise with strengthened IPR under large cost saving from contractual R&D and the relatively strong bargaining position of the Southern firm. Fifth, we illustrate how a policy mix of IPR and FDI subsidy in developing countries affects R&D activi-

ties adding an offshore R&D subsidiary as an additional organizational form. Our analysis suggests that stronger patent protection is likely to expand the international contractual R&D activities. Alternatively, developing countries with weak patent protection could offer incentives to multinational firms in establishing offshore R&D subsidiaries by reducing their R&D subsidiary setup costs.

Our paper is most closely related to Chen and Puttitanun (2005).[5] They consider a model of a developing country that has two sectors, an import sector and a local sector. While stronger IPR encourage domestic innovation in the local sector, it also makes it more difficult for a domestic imitator to imitate the more advanced foreign firm's technology in the import sector. Hence the choice of IPR in developing countries needs to balance these two effects. In contrast, we focus on the role of IPR in the context where both a MNE and a local firm have competitive advantage in one stage of the R&D chain of a complex technology in the same sector. We also consider the possibility that an original imitator in developing countries may not be an imitator forever. Instead, it could eventually become a potential innovator.

The rest of our paper is organized as follows. In the next section we present a basic model of R&D offshore outsourcing. We analyze the equilibrium outcomes under no patent protection in section 3 and under strengthened patent protection in section 4, respectively. We then demonstrate how the equilibrium outcomes will be changed by allowing for the multinationals firms' strategic behavior on IPR enforcement in section 5. The impacts of strengthened IPR on the welfare of the developing country

[5]Our paper is also related to the literature on outsourcing. See Grossman and Helpman (2005), Jones (2005), Chen, et al., (2004), Riezman and Wang (2008), Mukherjee and Dinda (forthcoming), among others. However, the above literature does not look into the international R&D outsourcing and the impacts of intellectual property in developing countries from a North-South perspective, which is the focus of our paper.

are studied in section 6. We further examine how the Southern government can choose a policy mix of IPR and FDI subsidy by adding an R&D subsidiary as an alternative organizational form in section 7. We offer concluding remarks and some possible extensions in the final section.

2 The basic setup

In this section we lay out a model which captures the recent trend of internationalization of R&D activities, as discussed in the introduction section. Consider a market with two firms, one N firm (the multinational) and one S firm (the local),[6] producing a homogeneous product using two components and competing in Cournot fashion. If a represents the market size of the world, the inverse-demand function for our product is given by $P = a - q$, where P is the price of the product and q the quantity produced.[7] Let $c_i (i = 1, 2)$ denote firms' marginal production costs related to the first and second component, respectively, before process innovation or imitation.[8] Firms' marginal production costs related to component i can be reduced to $\tilde{c}_i$ by process innovation and to $\alpha\tilde{c}_i$ by imitation. Here α is a parameter representing firms' imitation capacity given by such characteristics of the South as education level and infrastructure, where a lower value of α indicates higher imitation capacity. Since the imitator has no access to tacit knowledge including know-how and information

[6]Our findings remain qualitatively intact with different numbers of Southern firms engaging in quantity competition.

[7]We assume that market size a is sufficiently greater than marginal costs to ensure positive production of both firms.

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

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 firms' marginal cost but the decline is greater in the latter case.

Assume that the N firm has competitive advantage in conducting R&D on component 1 because it has higher technological level; the S firm has competitive advantage in conducting R&D on component 2 because it has the advantage of lower labor cost and some other advantages discussed in the introduction section. To focus on the analysis of firms' incentive to undertake contractual R&D, we assume that only the N firm conducts process innovation on component 1 before the game starts. We also assume that the N firm produces in the North and the S firm produces in the South.[9] Let R_N and R_S denote R&D costs on component 2 of the N firm and the S firm. Here we assume $R_S < R_N$, reflecting the competitive advantage of the S firm in conducting R&D on component 2. Therefore the N firm can either undertake in-house R&D on component 2 or outsource the R&D on component 2 to the S firm.[10] If offshore outsourcing of R&D occurs, we assume that the N firm offers

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

[10]In principle, the N firm could also license the technology on component 1 to the S firm to take advantage of the low cost in the South. However, licensing of the technology on component 1 from the N firm to the S firm is often not feasible in the real world for two reasons. First, the N firm tends to protect its core technologies from leakage. Second, transferring the core technology would incur high technology transfer cost due to the low learning capacity in the South. For example, in the pharmaceutical industry it is not easy for the N firm to license the core technology because these big N pharmaceutical firms have to conduct a lot of worldwide tests to satisfy the FDA (Federal Drug Authority) in the USA, which are not feasible for the S firms as the amount of resources are beyond their reach.

a take-it-or-leave-it contract with a lump-sum license fee to the S firm which the S firm accepts if it is not worse-off compared to that without licensing. Consequently, the S firm gets its reservation value and all the surplus accrues to the N firm. We denote the lump-sum license fee by L, which must be paid to acquire the technology on component 2 innovated by the S firm.

The time sequence of the game is as follows. In the first stage, the N firm offers the R&D contract which the S firm may accept or reject. If the contract is accepted, the S firm undertakes R&D in component 2 and licenses it to the N firm in stage 2 and both firms compete in quantities in a Cournot setting in stage 3. If the contract is rejected, in the second stage the N firm undertakes in-house R&D on component 2 and the S firm chooses among three strategies: (i) imitating the technology on component 1 without undertaking R&D on component 2; (ii) conducting R&D in component 2 without imitating the technology on component 1; (iii) imitating the technology on component 1 along with undertaking R&D on component 2.[11] Both firms compete in quantities in a Cournot setting and profits are realized in stage 3.[12]

In this context we assume that $f(\ ,\ )$ represents the production relationship between marginal production costs of components and the firms' marginal production cost of the product, where the first (second) argument is the marginal cost of the

[11]By assuming that $R_S < \pi_S(\tilde{c}_1 + \tilde{c}_2, c_1 + \tilde{c}_2) - \pi_S(\tilde{c}_1 + \tilde{c}_2, c_1 + c_2)$, strategy (ii) always dominates the strategy of no imitation or no innovation, a potential fourth strategy. This assumption is made to minimize technical details that are not essential for our results. Our findings remain intact if we relax this assumption.

[12]We rule out the possibility that the N firm can imitate the S firm's technology on component 2 to avoid the complication of the model. One practical justification for this assumption is the S firm not only applies for a patent for its technology in developing counties, but also in developed countries. Hence, it makes it harder for the N firm to imitate the S firm's technology as the patent protection is much stronger in developed countries.

component 1(component 2).[13] Suppose the N firm's marginal production cost of the product are c_N and $\tilde{c}_N$ in the absence and presence of process R&D on component 2, respectively. Thus, we have $c_N = f(\tilde{c}_1, c_2)$ and $\tilde{c}_N = f(\tilde{c}_1, \tilde{c}_2)$. Let the S firm's marginal production cost be c_S^α, $\tilde{c}_S$ and $\tilde{c}_S^\alpha$ under strategy (i), (ii) and (iii), respectively. Hence, we have $\tilde{c}_S = f(c_1, \tilde{c}_2)$, $c_S^\alpha = f(\alpha\tilde{c}_1, c_2)$ and $\tilde{c}_S^\alpha = f(\alpha\tilde{c}_1, \tilde{c}_2)$. We also denote the profit function of firm j by $\pi_j(\ ,\ )(j = N, S)$, where the first (second) argument is the marginal cost of the N firm (the S firm).

We now proceed to discuss the behavior and payoff of firms in two cases: one with no patent protection and the other with strengthened patent protection.

3 Under no patent protection

First consider the scenario where there is no patent protection in the developing country. Strength of patent protection of a country refers to the adequacy the laws and regulations it has in place as well as enforcement mechanism in order to provide transparency and certainty for investors, licensees, and customers (Maskus 2004). In our context no patent protection means that firms do not need to pay an imitation cost if there is an infringement of existing patents.

We begin by analyzing the case with a successful licensing. In this event the S firm undertakes R&D on component 2 and licenses it to the N firm in stage 2. We initially focus on the case where there is no imitation under licensing. Hence, the payoffs of the N and the S firm under licensing 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 the N firm's licensing contract is rejected, the N firm undertakes in-house R&D on component 2 and the S firm chooses among

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

three options mentioned in section 2. Under no patent protection strategy (ii) is always dominated by strategy (iii) because the S firm does not need to pay the imitation cost in case of patent infringement. Thus, we focus on the comparison of payoffs under strategy (i) and (iii). If the S firm chooses to imitate the technology on component 1 without undertaking R&D in component 2 (strategy (i)), the payoffs of the N firm and the S firm are given by $\pi_N(\tilde{c}_N, c_S^\alpha) - R_N$ and $\pi_S(\tilde{c}_N, c_S^\alpha)$, respectively. If the S firm chooses to conduct R&D on component 2 along with imitating the technology on component 1 (strategy (iii)), the payoffs of the N firm and the S firm are $\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N$ and $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S$, respectively. Licensing could only occur if the joint profit under licensing is greater than that of strategy (i) and that of strategy (iii).

By comparing the above payoff functions, we find that the S firm's profit under strategy (iii) is greater than that under strategy (i) if the S firm's R&D cost on component 2 is less than a threshold value $K_1 = \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, where K_1 denotes the difference of the S firm's production profit under strategy (iii) and strategy (i). Next, we find that the joint profit of both firms under licensing is greater than that under strategy (i) if the S firm's R&D cost on component 2 is less than a threshold value $K_2 = R_N + \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$, where K_2 denotes the difference between the joint production profit under licensing and total joint payoffs reflecting both production profits and R&D cost under strategy (i).[14] We then summarize our results as follows: (1) the S firm would accept the contract and undertake contractual R&D with its payoff under strategy (iii) as reservation value if $R_S < K_1$; (2) the S firm would accept the contract and undertake contractual R&D with its payoff under strategy (i) as reservation value if $K_1 < R_S < K_2$; (3) the S firm would deny the contract and imitate the technology on component 1 without

[14]For simplicity we assume that $K_1 < K_2$.

undertaking R&D on component 2 if $R_S > K_2$ (See Appendix A for proof).

In summary, contractual R&D only occurs when $R_S < K_2$, where the value of K_2 depends on three factors: the N firm's R&D cost on component 2, the joint profit under contractual R&D and the joint profit under imitation which is affected by the S firm's imitation capacity. This result demonstrates that in an environment where there is no patent protection in the South contractual R&D between the N firm and the S firm becomes more likely under low S firm's R&D cost and high N firm's R&D cost on component 2. Further, the lower the S firm's imitation capacity, the more likely is contractual R&D.

4 Under strengthened patent protection

Now consider the case with strengthened patent protection, where the Southern country provides adequate laws and regulations as well as enforcement. It implies that firms have to pay an imitation cost if there is an infringement of existing patents. We first analyze the scenario where the N firm always has the incentive for strong IPR enforcement, in the sense that the N firm always brings a law suit against the S firm if the S firm imitates the N firm's process innovation on component 1. In this event firms have to pay an imitation cost if there is an infringement of existing patents. Let I denote the S firm's imitation cost in the form of fines from law suits.

In this event the payoffs of the N and the S firm with a successful licensing 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.[15] In the absence of

[15]Our results would be essentially the same if we consider the possibility that the S firm commits not to produce after a successful licensing under strengthened IPR. Under such circumstances the N firm is a monopoly in the market and the S firm does not produce in the third stage.

licensing, the payoffs of the N firm and the S firm are given by $\pi_N(\tilde{c}_N, c_S^\alpha) - R_N + I$ and $\pi_S(\tilde{c}_N, c_S^\alpha) - I$ under strategy (i); $\pi_N(\tilde{c}_N, \tilde{c}_S) - R_N$ and $\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$ under strategy (ii); $\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N + I$ and $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - I$ under strategy (iii).

By comparing the above payoff functions, we find that the joint profit of both firms under licensing is greater than that under strategy (i) if the S firm's R&D cost on component 2 is less than a threshold value $K_2' = R_N + \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha) + I$, where K_2' denotes the difference between the joint production profit under licensing and total joint payoff under strategy (i). Thus, we find that a successful licensing only occurs for $R_S < K_2'$ and no licensing occurs otherwise. By comparing the equilibrium under no patent protection and that under strengthened patent protection, it can be shown that it is more likely for the S firm to undertake contractual R&D in component 2 under strengthened patent protection than under no patent protection as K_2' is greater than K_2 (see Appendix B for proof).[16] Hence, we have the following proposition.

Proposition 1: *Patent protection increases firms' incentive for specialization in undertaking R&D when each firm has competitive advantage in research and development in one component respectively*.

The economic intuition is as follows. Under no patent protection, it could be more profitable for firms to imitate their competitor's technology as they do not need

[16]If we consider the possibility that the S firm commits not to produce after a successful licensing under strengthened IPR, contractual R&D occurs if the S firm's R&D cost on component 2 is less than a threshold value $K_2'' = R_N + \pi_M(\tilde{c}_N) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha) + I$, where $\pi_M(\tilde{c}_N)$ denotes the N firm's monopoly production profit under a successful licensing. It is easy to show $K_2'' > K' > K$. This implies that allowing for the S firm commits not to produce after a successful licensing actually expands the range of parameter values under which adoption of strong IPR promotes contractual R&D in the developing country. Hence our results will be strengthened under such circumstances.

to pay an imitation cost in the form of fines from the law suits. Strengthened patent protection thus reduces firms' incentive to imitate as they face the imitation cost and enhances the S firm's incentive to shift from imitation to conducting cooperative R&D. The above analysis suggests that in an environment where both the multinational and the local firms have their own competitive advantage in one stage of the R&D chain, strengthened patent protection encourages the specialization of R&D and therefore contractual R&D activities between the North and the South.

5 Strategic IPR enforcement

In previous sections we have demonstrated that patent protection encourages international specialization in R&D, in particular in contractual R&D activities between multinationals and local firms. We next turn to an analysis on how firms' incentive on IPR enforcement and the equilibrium results can be changed by multinationals firms' strategic behavior on IPR enforcement.

In section 4 we analyzed the scenario where the N firm always chooses to bring a law suit against the S firm in case of patent infringement. In this section we discuss the possibility that the N firm may choose strategic weak IPR enforcement even though the Southern government provides adequate laws and regulations, in the sense that the N firm may choose not to bring a law suit against the S firm when the S firm imitates the N firm's technology on component 1. To include the N firm's strategic incentive on IPR enforcement, the time sequence of the game is modified as follows. In the first stage, given the Southern patent scope, the N firm chooses between strong enforcement and strategic weak enforcement under contractual R&D. If the N firm chooses strong enforcement, the S firm does not imitate the N firm's

technology on component 1 under contractual R&D, knowing the N firm will bring a lawsuit against it with patent infringement. If the N firm chooses strategic weak enforcement, the S firm is permitted to imitate the N firm's technology on component 1 under contractual R&D. If the contract is accepted, the S firm undertakes R&D on component 2 and licenses it to the N firm in stage 2. The S firm imitates the N firm's technology on component 1 if the N firm chooses strategic weak enforcement and does not imitate otherwise. If the contract is rejected, the N firm undertakes in-house R&D on component 2 and the S firm chooses among the three strategies discussed in section 2 in stage 2. Under this circumstance the N firm always chooses strong IPR enforcement with patent infringement. Both firms compete in quantities in a Cournot setting in stage 3.

As shown in Appendix B, with strong enforcement the contractual R&D occurs if $R_S < K_2'$ and does not occur otherwise. As the N firm has the new option of strategic weak IPR enforcement, the S firm's outside options do not change. Hence, the payoffs of both firms in the absence of a successful R&D contract are the same as those in section 4. In the presence of a successful R&D contract, the payoffs of the N and the S firm are given by $\pi_N(\tilde{c}_N, \tilde{c}_S) - L$ and $\pi_S(\tilde{c}_N, \tilde{c}_S) + L - R_S$ with strong enforcement. They become $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) - L$ and $\pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) + L - R_S$ with strategic weak enforcement. Accordingly, the joint profit of the N and S firm under contractual R&D is $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$ with strong enforcement and $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - R_S$ with weak enforcement. As the outside options of contractual R&D with strong enforcement are the same as those with weak enforcement, the licensing equilibrium becomes more likely the greater the joint profit under licensing. Thus, we focus on the comparison of joint profit under contractual R&D with strong enforcement and that with strategic weak enforcement.

In a Cournot duopoly model the industry profit increases as one of the firms

are more efficient given that these two firms are reasonably close in terms of their initial technologies (Marjit 1990).[17] More specifically, in our setting it can be inferred that the industry profit under strategic weak IPR enforcement is greater than that under strong enforcement if $c_S^{\alpha} < \frac{a+4\tilde{c}_N}{5}$.[18] This result suggests that strategic IPR weak enforcement increases the joint industry profit if the technology gap of the N firm and the S firm undertaking the potential contractual R&D is reasonably small. Further, the N firm is better off under strategic weak IPR enforcement than that under strong enforcement as the S firm only gets its reservation value and all surplus accrues to the N firm.

Let $\overline{K}$ denote $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, c_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + R_N + I$, which is the difference between the joint production profit under contractual R&D with strategic weak IPR enforcement and total joint payoff under strategy (i). Note that the joint production profit under contractual R&D with strategic weak IPR enforcement is greater than that with strong IPR enforcement, thus it can be shown that $\overline{K}$ is greater than K_2'. Similar to the analysis in section 4, we now have the following equilibrium results: (1) Contractual R&D occurs for $R_S < \overline{K}$ where the S firm undertakes R&D on component 2 along with imitating the N firm's technology on component 1 without a lawsuit from the N firm; (2) Contractual R&D does not occur otherwise. Comparing the equilibrium results with the option of strategic weak enforcement and those with strong enforcement discussed in section 4, it can be shown that for $K_2' < R_S < \overline{K}$ contractual R&D would occur if the N firm has the option of

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

[18] The condition that $c_S^{\alpha} < \frac{a+4\tilde{c}_N}{5}$ also guarantees $\tilde{c}_S < \frac{a+4\tilde{c}_N}{5}$.

strategic weak IPR enforcement, but would not occur with strong IPR enforcement (See Appendix C for proof). Hence, it is more likely for the S firm to undertake contractual R&D on component 2 by allowing for the option of strategic weak IPR enforcement. Hence, the following proposition is immediate.

Proposition 2: *The N firm's strategic behavior on weak enforcement of IPR may increase the possibility of contractual R&D in developing countries.*

The intuition is as follows. If the S firm imitates the technology on component 1 and the N firm chooses not to bring in a lawsuit against the S firm, the S firm produces more efficiently while the N firm's marginal production cost does not change, which in turn increases the total industry profit and makes the licensing more likely. The N firm's payoff increases since it extracts all the increase in the industry profit as it makes a take-it-or-leave-it contract to the S firm. Under such circumstances the option of strategic weak IPR enforcement encourages contractual R&D activities.

We illustrate the above equilibrium results under different circumstances in Figure 1, where the horizontal axis represents the S firm's R&D cost on component 2 and the vertical axis represents the joint profits. Here Π_C^{NP}, Π_C^{SP} and Π_C^{WE} are defined as the joint profit under contractual R&D with no patent protection, strong patent protection with strong enforcement and strong patent protection with strategic weak enforcement, respectively. Π_I^{NP}, Π_I^{SP} and Π_I^{WE} are defined as the joint profit under imitation without innovation with no patent protection, strong patent protection with strong enforcement and strong patent protection with strategic weak enforcement, respectively. The joint profits under contractual R&D correspond to the downward sloping lines as they decrease with the S firm's R&D cost on component 2. The joint profits under imitation without innovation correspond to the horizontal lines as they are independent of the S firm's R&D cost on component 2.

As shown in Figure 1, in the first case where there is no patent protection, the joint profit under contractual R&D (Π_C^{NP}) exceeds that under imitation without innovation (Π_I^{NP}) if $R_S < K_2$ and vice versa, thus the curve of Π_C^{NP} is above the curve of Π_I^{NP} for $R_S < K_2$ and below the curve of Π_I^{NP} for $R_S > K_2$. Hence, under no patent protection contractual R&D is the equilibrium if R_S is less than the threshold value K_2 and imitation without innovation is the equilibrium otherwise. With strengthened patent protection along with strong enforcement, the joint profit under contractual R&D (Π_C^{SP}) does not change ($\Pi_C^{SP} = \Pi_C^{NP}$) while the joint profit under imitation without innovation (Π_I^{SP}) is lower due to the presence of the imitation cost ($\Pi_I^{SP} < \Pi_I^{NP}$). Therefore, the two curves, Π_C^{NP} and Π_C^{SP}, coincide with each other while the curve of Π_I^{SP} is below the curve of Π_I^{NP}, accordingly the threshold value becomes K_2'. Thus, in the case of strengthened patent protection, contractual R&D is the equilibrium if R_S is less than the threshold value K_2' and imitation without innovation is the equilibrium otherwise. Finally, in the event of strategic weak IPR enforcement, the joint profit under contractual R&D (Π_C^{WE}) expands due to the increase in the S firm's efficiency ($\Pi_C^{WE} > \Pi_C^{SP}$) while the joint profit under imitation without innovation (Π_I^{WE}) remains unchanged ($\Pi_I^{WE} = \Pi_I^{SP}$). It follows that the curves of Π_I^{WE} and Π_I^{SP} coincide with each other while the curve of Π_C^{WE} is above the curve of Π_C^{SP}, hence the threshold value changes to $\overline{K}$.[19] That is, in the case of strategic weak IPR enforcement, contractual R&D is the equilibrium if R_S is less than the threshold value $\overline{K}$ and imitation without innovation is the equilibrium otherwise. In Appendix A and B, we show that $K_2 < K_2' < \overline{K}$.

[19]Note that K_1 is not shown in the figure because it involves the comparison of the S firm's profit under strategy (i) and (iii), but not the comparison of the joint profit.

6 Welfare impacts of IPR policy

We have discussed the role of IPR in encouraging contractual R&D activity between the N firm and the S firm. It is of interest to evaluate the impacts of changes in the patent regime on the welfare of the Southern country, defined as the sum of local consumer surplus and the S firm's production profit. The detailed calculations in this context are complex and, to save space, we simply overview the results here (See Appendix D for mathematical computations).

6.1 Welfare impacts of strengthened IPR

We first discuss the change in Southern welfare from no patent protection to strengthened patent protection. Here we focus on the analysis of the case where in equilibrium the S firm is an imitator without innovation under no patent protection and becomes an innovator undertaking contractual R&D under strengthened patent protection. The policy shift from no patent protection to strengthened IPR in developing countries has two distinct effects on the domestic welfare. First, this policy shift encourages contractual R&D, which increases the productivity of the S firm and expands consumption in the Southern market. Second, the increase in imitation cost decreases the S firm's profit under imitation, thereby decreasing its reservation value under licensing. Accordingly, strengthened IPR decreases the S firm's profit under licensing. However, the consumer gain due to the increase in the S firm's productivity becomes larger with the increase in the cost saving shifting from imitation to innovation. Further, as the S firm's bargaining strength increases, the S firm's profit as well as the Southern welfare will be enhanced with the strengthened IPR.[20] In

[20]The S firm's bargaining strength will be increased as the S firm may license its technology on one component to multiple N firms who produce differentiated goods but all use the S firm's technology

brief, strengthened patent protection will raise local welfare with large cost saving from innovation and the relatively strong bargaining position of the Southern firm.

6.2 Welfare impacts of strategic IPR Enforcement

For the change in Southern welfare when shifting from strong enforcement to strategic weak enforcement, we mainly discuss the case where the equilibrium regime is imitation without innovation under strong enforcement and it becomes contractual R&D under strategic weak enforcement. Upon reaching the licensing equilibrium range, the S firm's productivity is increased which expands consumer gains in the Southern market. The S firm's profit does not change under strategic weak IPR enforcement as it gets the same reservation value as that under strong IPR enforcement. Accordingly, the Southern welfare rises with the N firm's strategic weak IPR enforcement. However, given the choice of imitating the N firm's process innovation on component 1, the S firm may have less incentive to undertake R&D on component 1, thereby reducing the S firm's bargaining strength and diminishing the Southern welfare if we extend the evaluation to a longer time horizon.

7 Adding offshore R&D subsidiary

We have analyzed the multinational firm's choice between undertaking in-house R&D and outsourcing the contractual R&D to a local firm. An alternative organizational choice for a multinational firm is to establish a wholly-owned R&D subsidiary in developing countries. Increasingly, multinational firms have established not only sales and manufacturing operations but also research and development facilities in

as one stage in the R&D chain. We will discuss this situation in section 8.

developing countries. By setting up R&D subsidiaries in developing countries, multinational firms are able to take advantage of lower R&D cost in developing countries. To capture this feature, we now incorporate a simple specification of an R&D subsidiary into the model.

Suppose the N firm has the option of establishing an R&D subsidiary in the South. Following Antràs and Helpman (2004), we assume that the fixed organizational cost under integration abroad (set up an R&D subsidiary) is greater than that under outsourcing (conducting contractual R&D activities with local firms). To simplify the analysis, we assume that a setup cost f is incurred under integration (set up an R&D subsidiary) while no setup cost is incurred under outsourcing. We also assume that the R&D cost on component 2 of the S subsidiary is R_S, the same as that of the S firm undertaking contractual R&D, reflecting the fact that the S subsidiary is also able to take advantage of lower R&D cost in developing countries. As a result, the cost difference between conducting R&D through an R&D subsidiary and through outsourcing is the setup cost f.[21]

In this setup, the N firm has two outside options: conducting in-house R&D in the North and setting up an R&D subsidiary in the South, while the S firm has three outside options set out in previous sections in case of a breakup of the negotiation of contractual R&D. Working through the payoff functions we have the following results.[22] If the subsidiary setup costs are large and patent protection is weak, in equilibrium the N firm conducts in-house R&D. In this event the N firm does not choose an R&D subsidiary due to the large setup cost, while the S firm has no incentive to undertake contractual R&D due to the high reservation value under imitation. As the Southern countries strengthens its patent protection, the

[21] In this section we focus on the case without strategic weak IPR enforcement.

[22] See Appendix E for proof.

equilibrium shifts from integration at home (conducting in-house R&D in the North) to outsourcing (undertaking contractual R&D), where the Southern firm shifts from an imitator to an innovator undertaking contractual R&D. If subsidiary setup costs are sufficiently small while patent protection is weak, in equilibrium the N firm chooses to conduct R&D via an R&D subsidiary. Strengthened patent protection shifts the equilibrium from integration abroad (setting up an R&D subsidiary) to outsourcing (undertaking contractual R&D) in this event.

The above results can be characterized as follows. In developing countries where subsidiary setup costs are large and patent protection is weak, the N firm chooses to conduct in-house R&D in the North. Strengthened patent protection encourages contractual R&D as it increases the S firm's incentive to change from an imitator to an innovator. Alternatively, the Southern country with weak patent protection may be able to attract an R&D subsidiary by reducing the setup costs of the R&D subsidiary. In particular, the Southern government could focus on the improvement of infrastructure, the institutions as well as providing multinational firms with FDI subsidies including job-creation subsidies, tax cut and even the construction of industrial facilities. Strengthened patent protection could further encourage contractual R&D activities between the N firm and the S firm.

8 Concluding remarks

This paper offers a new perspective on the protection of intellectual property in developing countries. We develop a model to illustrate the important role of intellectual property in shaping the landscape of international specialization in research and development. Our analysis yields several interesting results. First, by reducing the

Southern firm's profits under imitation, strengthened intellectual property protection in developing countries increases the Southern firm's incentive to undertake contractual R&D, thereby encouraging the international specialization in R&D. Second, the multinational firm's strategic behavior on weak enforcement of IPR may encourage contractual R&D in developing countries. This is due to the increase in the total industry profit extracted by the multinational firm as the S firm produces more efficiently under strategic weak IPR enforcement. Further, we find that Southern welfare could rise with strengthened IPR under large cost saving from innovation and the relatively strong bargaining position of the Southern firm. Finally, we show how a policy mix of IPR and FDI subsidy in developing countries affects R&D activities by adding an offshore R&D subsidiary as an alternative organizational form.

Given the recent surge in international fragmentation in both production and research and development, the policy implications we find here may be helpful for policymakers in developing countries in fashioning their reforms in intellectual property. Specifically, our analysis suggests that stronger patent protection is likely to expand the international contractual R&D activities where both a multinational firm and a local firm have competitive advantage in one stage of the R&D chain respectively. Alternatively, the Southern country with weak patent protection could offer incentives to multinational firms in establishing offshore R&D subsidiaries by reducing their R&D subsidiary setup costs.

Our analysis can be extended to more general environments. We have assumed that the S firm can only license its technology on one component of a product to one N firm. However, in the real world it is possible that the S firm may license its technology on one component to multiple N firms who produce differentiated goods but all use the S firm's technology as one stage in the R&D chain. For example, a lot of pharmaceutical firms in India are licensing the technology on one molecule to

multiple multinational firms who use molecule as one component of their product. If we include this possibility in our model, the S firm's bargaining power will be increased in the sense that there are a large number of potential buyers. It is likely that the N firms only get their reservation values and all the surplus accrues to the S firm. Hence, the S firm has more incentive to change from an imitator to an innovator who undertakes contractual R&D and our conclusions will be strengthened.

Another promising avenue for future research is to extend the analysis to examine the impact of a policy mix of R&D subsidy policy and IPR policy on R&D offshore outsourcing. The R&D subsidy policy in developing countries can be affected by their IPR policy as strengthened IPR policy may change domestic firms' incentive to undertake contractual R&D. This analysis will be important for developing countries as R&D subsidy policy plays a vital role in shaping domestic innovative capacity which are considered to be central to domestic economic growth.

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Appendix A: Equilibrium results under no patent protection.

This appendix provides a detailed illustration of the equilibrium results in the presence of licensing under no patent protection.

The Generalized Nash Bargaining Solution is

$\pi_N = d_N + \tau(\pi - d_N - d_S)$ and $\pi_S = d_S + (1-\tau)(\pi - d_N - d_S)$. Here, π_N and π_S are the Nash bargaining solutions; π is the joint profit of both firms under licensing; τ is the bargaining power of player N, and $1-\tau$ is the bargaining power of player S; d_N and d_S are the disagreement points.

In this paper we assume that the N firm offers a take-it-or-leave-it contract to the S firm in this paper, thus the N firm's bargaining power τ is equal to 1. And the payoffs of the N and S firm under a successful licensing are

$\pi_N = d_N + (\pi - d_N - d_S)$ and $\pi_S = d_S$.

Hence, a successful licensing only occurs when the joint profit of both firms under licensing is greater than that under an outside option.

The joint profit under licensing is given by $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$. And the joint profit under strategy (i), (ii) and (iii) is given by

$\pi_N(\tilde{c}_N, c_S^\alpha) + \pi_S(\tilde{c}_N, c_S^\alpha) - R_N$, $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_N - R_S$, and $\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) + \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N - R_S$, respectively.

It is obvious that the joint profit under strategy (ii) is always less than that under licensing.

For simplicity, we assume that the N firm's R&D cost on component 2 is so high that $R_N > \pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) + \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, which implies that the joint profit under licensing is greater than that under strategy (iii).

The S firm's payoffs under strategy (i), (ii) and (iii) under no patent protection are $\pi_S(\tilde{c}_N, c_S^\alpha)$, $\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$ and $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S$, respectively. It is straightforward that its payoff under strategy (ii) is always dominated by strategy (iii) because the S firm does not need to pay the imitation cost in case of patent infringement under no patent protection. Thus, we focus on the analysis on payoffs of strategy (i) and (iii).

Let K_1 denote $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$. Then strategy (iii) dominates strategy (i) for the S firm if $R_S < K_1$. Let K_2 denote $R_N + \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$. Thus, the joint profit under licensing is greater than that under strategy (i) if $R_S < K_2$. For simplicity we assume $K_1 < K_2$.

Therefore, we have the following findings:

If $R_S > K_1$, strategy (i) dominates strategy (iii) for the S firm. A successful licensing where the reservation values are the payoffs under strategy (i) occurs if $K_1 < R_S < K_2$ and will not occur if $R_S > K_2$.

If $R_S < K_1$, strategy (iii) dominates strategy (i) for the S firm. In this case a successful licensing where the reservation values are payoffs under strategy (iii) always occurs.

In short, a successful licensing occurs where the reservation values are payoffs under strategy (iii) for $R_S < K_1$; a successful licensing occurs where the reservation values are the payoffs under strategy (i) for $K_1 < R_S < K_2$ and no licensing occurs for $R_S > K_2$. The corresponding licensing fee is $L = \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$ for $R_S < K_1$ and $L = R_S + \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$ for $K_1 < R_S < K_2$.

Appendix B: Proof of Proposition 1.

With strengthened patent protection, the joint profit under licensing is given by $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$. And the joint profit under strategy (i), (ii) and (iii) is given by $\pi_N(\tilde{c}_N, c_S^\alpha) + \pi_S(\tilde{c}_N, c_S^\alpha) - R_N$, $\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - R_N - R_S$, and $\pi_N(\tilde{c}_N, \tilde{c}_S^\alpha) + \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_N - R_S$, respectively.

The S firm's payoff under strategy (i), (ii) and (iii) in the absence of a successful licensing under strengthened patent protection are $\pi_S(\tilde{c}_N, c_S^\alpha) - I$, $\pi_S(\tilde{c}_N, \tilde{c}_S) - R_S$ and $\pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - R_S - I$, respectively. Here we discuss two cases.

I. If $I < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, strategy (iii) dominates strategy (ii) and the analysis is similar to that in Appendix A. Let K_2' denote $R_N + \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha) + I$. We then have the following findings:

If $R_S > K_1$, strategy (i) dominates strategy (iii) for the S firm. The S firm chooses strategy (i) in stage 2. A successful licensing where the reservation values are the payoffs under strategy (i) occurs if $K_1 < R_S < K_2'$ and will not occur if $R_S > K_2'$.

If $R_S < K_1$, strategy (iii) dominates strategy (i) for the S firm. In this case a successful licensing where the reservation values are payoffs under strategy (iii) always occurs.

In summary, a successful licensing occurs where the reservation values are payoffs under strategy (iii) for $R_S < K_1$; a successful licensing where the reservation values are the payoffs under strategy (i) occurs for $K_1 < R_S < K_2'$ and no licensing occurs for $R_S > K_2'$ when $I < \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. Therefore, a successful licensing only occurs for $R_S < K_2'$, which shows that strengthened patent protection increases firms' incentive for specialization in undertaking R&D as K_2' is greater than K_2.

II. If $I > \pi_S(\tilde{c}_N, \tilde{c}_S^\alpha) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, strategy (ii) dominates strategy (iii). Let K_3

denote $I + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, c_S^{\alpha})$. Thus, we have the following findings:

If $R_S < K_3$, strategy (ii) dominates strategy (i). Since the joint profit under strategy (ii) is always greater than that under licensing, a successful licensing always occurs where the reservation values are payoffs under strategy (ii).

If $R_S > K_3$, strategy (i) dominates strategy (ii). The S firm chooses strategy (i) in stage 2. A successful licensing occurs where the reservation values are the payoffs under strategy (i) if $K_3 < R_S < K_2'$ and will not occur if $R_S > K_2'$.[23]

In summary, a successful licensing occurs where the reservation values are payoffs under strategy (ii) for $R_S < K_3$; a successful licensing where the reservation values are the payoffs under strategy (i) occurs for $K_3 < R_S < K_2'$ and no licensing occurs for $R_S > K_2'$ when $I > \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. Again, it shows that strengthened patent protection increases firms' incentive for specialization in undertaking R&D as K_2' is greater than K_2.

Appendix C: Proof of Proposition 2.

This appendix proves Proposition 2.

As shown in Appendix B, with strong enforcement the contractual licensing occurs if $R_S > K_2'$ and does not occur otherwise. As the N firm has the new option of strategic weak IPR enforcement, the S firm's outside options do not change. Accordingly both firms' reservation values without licensing have no change, but the joint profit under licensing will be changed due to the N firm' new option of strategic weak IPR enforcement. The joint profit of the N and S firm under contractual R&D is

[23]Here we assume that $K_2' > K_3$. The conclusion will not be changed if we relax this assumption.

$\pi_N(\tilde{c}_N, \tilde{c}_S)+\pi_S(\tilde{c}_N, \tilde{c}_S)-R_S$ with strong enforcement and $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha})+\pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha})-R_S$ with weak enforcement. We show that the joint industry profit with weak enforcement is greater than that with strong enforcement in the text, therefore the N firm opts for strategic weak enforcement under contractual R&D.

Let $\overline{K}$ denote $\pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, c_S^{\alpha}) - \pi_S(\tilde{c}_N, c_S^{\alpha}) + R_N + I$. Then the joint profit under contractual R&D with weak enforcement is greater than that under outside options for $R_S < \overline{K}$. In short, we have the following equilibrium results: (1) Contractual R&D occurs for $R_S < \overline{K}$ where the S firm undertakes R&D on component 2 along with imitating the N firm's technology on component 1 without a lawsuit from the N firm; (2) Contractual R&D does not occur otherwise.

Comparing K_2' with $\overline{K}$, it is straightforward to show that $\overline{K}$ is greater than K_2'. Hence, we find that for $K_2' < R_S < \overline{K}$ contractual R&D would occur if the N firm has the option of strategic weak IPR enforcement, but would not occur with strong IPR enforcement.

Appendix D: Southern welfare

D.1 Southern welfare with no patent protection

Welfare of the Southern country is the sum of local consumer surplus and the S firm's production profit. Let q_N and q_S denote output of the N and S firm in the Southern country. Then the Southern welfare is given by $W_S = 0.5(q_S + q_N)^2 + \pi_S$.

For $R_S < K_1$ a successful licensing occurs where the reservation values are payoffs under strategy (iii), hence the southern welfare is given by $W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S)^2}{18} + \frac{(a+\tilde{c}_N-2\tilde{c}_S^{\alpha})^2}{9} - R_S$.

For $K_1 < R_S < K_2$ a successful licensing occurs where the reservation values are the payoffs under strategy (i), hence the southern welfare is given by

$$W_S = \frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18} + \frac{(a + \tilde{c}_N - 2c_S^{\alpha})^2}{9}.$$

For $R_S > K_2$, no licensing occurs and strategy (i) is the equilibrium. The Southern welfare is given by $W_S = \frac{(2a-\tilde{c}_N-c_S^{\alpha})^2}{18} + \frac{(a+\tilde{c}_N-2c_S^{\alpha})^2}{9}$.

D.2 Southern welfare with strengthened patent protection

Under strengthened patent protection, we mainly discuss the case when $I < \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S)$, which implies that strategy (iii) dominates strategy (ii) for the S firm.

For $R_S < K_1$, a successful licensing occurs where the reservation values are payoffs under strategy (iii). The Southern welfare is given by

$$W_S = \frac{(2a - \tilde{c}_N - \tilde{c}_S)^2}{18} + \frac{(a + \tilde{c}_N - 2\tilde{c}_S^{\alpha})^2}{9} - R_S - I.$$

For $K_1 < R_S < K_2'$, a successful licensing occurs where the reservation values are the payoffs under strategy (i). The Southern welfare is given by $W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^{\alpha})^2}{9} - I$.

For $K_S > K_2'$, no licensing occurs while strategy (i) is the equilibrium. The Southern welfare is given by $W_S = \frac{(2a-\tilde{c}_N-c_S^{\alpha})^2}{18} + \frac{(a+\tilde{c}_N-2c_S^{\alpha})^2}{9} - I$

D.3 Change in southern welfare shifting from no patent protection to strengthened patent protection

Here we focus on the analysis of the case where in equilibrium the S firm is an

imitator under no patent protection and becomes an innovator undertaking contractual R&D under strengthened patent protection for $K_2 < R_S < K_2'$. Under no patent protection, the Southern welfare is $W_S = \frac{(2a-\tilde{c}_N-c_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I$.

Under strengthened patent protection, it becomes

$$W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I.$$

D.4 Southern welfare with strategic weak enforcement

With the strategic weak enforcement, a successful licensing occurs where the reservation values are payoffs under strategy (iii) for $R_S < K_1$. There the Southern welfare is

$$W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2\tilde{c}_S^\alpha)^2}{9} - R_S$$

For $K_1 < R_S < \overline{K}$, a successful licensing occurs where the reservation values are the payoffs under strategy (i). Hence, the Southern welfare is $W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I$.

For $R_S > K_2'$, no licensing occurs while strategy (i) is the equilibrium. Hence, the Southern welfare is $W_S = \frac{(2a-\tilde{c}_N-c_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I$.

D.5 Change in southern welfare shifting from strong enforcement to strategic weak enforcement

Here we mainly discuss the case where the equilibrium regime is imitation without innovation under strong enforcement and it becomes contractual R&D under strategic weak enforcement for $K_2' < R_S < \overline{K}$.

Under strong enforcement, the Southern welfare is given by $W_S = \frac{(2a-\tilde{c}_N-c_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I$.

Under strategic weak enforcement it becomes $W_S = \frac{(2a-\tilde{c}_N-\tilde{c}_S^\alpha)^2}{18} + \frac{(a+\tilde{c}_N-2c_S^\alpha)^2}{9} - I$.

Appendix E: Equilibrium results with a R&D subsidiary

First consider the case that the setting up cost of a R&D subsidiary is sufficiently large ($f > R_N - R_S$). In this event the N firm's profit of conducting in-house R&D in the North is greater than that via a R&D subsidiary. As a result the equilibrium results are the same as those illustrated in Appendix B. Under weak patent protection the N firm conducts in-house R&D. As the Southern countries strengthened patent protection, the equilibrium shifts from integration at home (conducting in-house R&D in the North) to outsourcing (undertaking contractual R&D), where the Southern firm shifts from an imitator to an innovator.

Next consider the case that the setting up cost of a R&D subsidiary is sufficiently small ($f < R_N - R_S$). In this case the N firm's profit of conducting in-house R&D in the North is less than that via a R&D subsidiary. Under the circumstance that the S firm's payoff under option (i) has the highest value among the three outside options, the joint surplus of both firms is given by $+\pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, c_S^\alpha) - \pi_S(\tilde{c}_N, c_S^\alpha)$. As a result, contractual R&D would occur if $f > \pi_N(\tilde{c}_N, c_S^\alpha) + \pi_S(\tilde{c}_N, c_S^\alpha) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. Thus, under weak patent protection (small$I$), in equilibrium contractual R&D does not occur and the N firm chooses to conduct R&D via an R&D subsidiary. Strengthened patent protection (large$I$) shifts the equilibrium from integration abroad (set up an R&D subsidiary) to outsourcing (undertake contractual R&D). If the S firm's payoff under option (ii) has the highest value among the three

outside options, the joint surplus of both firms is given by $R_S + f$. In this case contractual R&D always happens and larger setting up cost increases the N firm's incentive of cooperating with the S firm. Under the circumstance that the S firm's payoff under option (iii) has the highest value among the three outside options, the joint surplus of both firms is given by $R_S + f + \pi_N(\tilde{c}_N, \tilde{c}_S) + \pi_S(\tilde{c}_N, \tilde{c}_S) - \pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha})$. Accordingly, contractual R&D would occur if $R_S + f > \pi_N(\tilde{c}_N, \tilde{c}_S^{\alpha}) + \pi_S(\tilde{c}_N, \tilde{c}_S^{\alpha}) - \pi_N(\tilde{c}_N, \tilde{c}_S) - \pi_S(\tilde{c}_N, \tilde{c}_S)$. In this case the analysis is similar to that where the S firm's payoff under option (i) has the highest value among the three outside options.

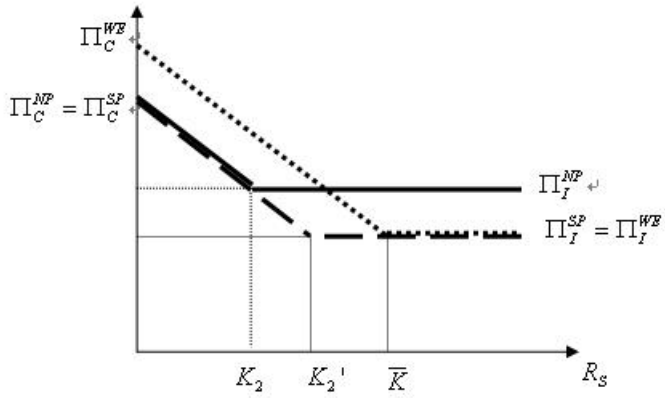

Figure 1. Equilibrium Results under Different Circumstances