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INTELLECTUAL PROPERTY RIGHTS, LICENSING, AND ECONOMIC GROWTH

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ABSTRACT

Intellectual Property Rights, Licensing, and Economic Growth

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We develop a dynamic general-equilibrium model of a Southern economy in which one firm type devotes resources to licensing new technologies for producing higher-quality goods from the North and another firm type expends resources to imitate the technologies. The licensee firm shares in the temporary monopoly rents with the Northern firm, with the rent share a declining function of the strength of intellectual property rights (IPRs) in the South. When the South undertakes an exogenous strengthening of IPRs, the effects on imitation, licensing, economic growth, and welfare depend on the elasticity of the rent share with respect to IPRs. With a low elasticity, tighter IPRs decrease the intensity of licensing new technologies, but have ambiguous effects on the intensity of imitation, growth, and welfare. With a high elasticity, stronger IPRs reduce both the intensity of imitation and economic growth, but have ambiguous impacts on licensing effort and welfare. Numerical simulations of the model confirm these possibilities under various parameter values.

Key words: Licensing, Imitation, Intellectual Property Rights

JEL Codes: F12, O34, D82

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NON-TECHNICAL SUMMARY

Recent theoretical studies of the implications of stronger intellectual property rights for the international diffusion of knowledge are pessimistic. In these papers, technology is transferred from innovative countries ("the North") to developing countries ("the South") through simple imitation, in which firms in the latter nations copy the new technology or product. In this context, the effect of stronger patent rights in the South is to raise the costs of imitation, thereby raising the short-run returns to R&D and raising innovation, while limiting the amount of technology transferred. In the long run, however, innovative countries find it more advantageous to devote more labour to the production of existing goods (against which there is less imitation risk) and, in consequence, the global rate of innovation slows down. Overall, the South suffers lower economic welfare and growth, the North gains from higher economic rents to existing products but loses from diminished growth, and the world is also made worse off. These results emerge in dynamic general-equilibrium models of technology transfer through imitation, where the channel of imitation is either international trade or foreign direct investment.

In this paper we show that this result is unduly pessimistic when the model is extended to cover another form of technology transfer, arm's-length licensing of know-how. We develop a dynamic general-equilibrium model of a Southern economy in which one firm type devotes resources to licensing new technologies for producing higher-quality goods from the North and another firm type expends resources to imitate those technologies. The licensee firm shares in the temporary monopoly rents with the Northern firm and faces imitation risk from other Southern firms. One direct effect of stronger patent rights in the South is to raise the costs of imitation, thereby expanding the instantaneous monopoly profits. However, another effect is to reduce the share of rents accruing to the licensee because stronger patents allow the Northern licensor to pay smaller rents in order to deter defection from the contract. As a result, there is an ambiguous impact in the model on key variables, including labour devoted to licensing and imitation, aggregate technology transfer, and growth. The crucial parameter on which we focus is the elasticity of the licensee's rent share with respect to a strengthening of patents. An inelastic rent share is akin to a weak expansion of

IPRs, which could expand imitation and growth. An elastic rent share is akin to a strong expansion of IPRs, which could reduce imitation but expand licensing efforts.

Overall, impacts on technology transfer and growth are ambiguous, which is a more optimistic message than that contained in prior literature. However, numerical simulations over reasonable parameter ranges still point to the likelihood that the strengthening of IPRs in the South, as envisioned by new global agreements, would tend to reduce Southern growth. This result is sensitive to the contracting model employed, however, and a fuller analysis of licensing could reverse it. Such analysis will be the subject of future work.

I. Introduction

Controversy persists over the role of intellectual property rights (IPRs) in helping developing countries gain access to knowledge on the global frontier. This paper studies the effects of IPRs on developing-country firms' incentives to license state-of-the-art technologies and on competitor firms' incentives to imitate them. It also investigates the effects of IPRs on economic growth and welfare in the developing country.

The literature on the effects of IPRs on innovation largely focuses on North-South trade models and studies whether the interests of the North and South to protect IPRs are in conflict. Chin and Grossman (1988) adopt a North-South Cournot duopoly model in which all innovation takes place in the North, and all imitation takes place in the South. They find that the interests of the North and South are generally opposed. Unless Northern R&D is very productive in lowering unit production costs, the Southern government's best policy is to "look the other way" while Southern firms infringe on Northern intellectual property. Diwan and Rodrik(1991) find that if preferences differ across regions for certain technological breakthroughs, then the South may protect Northern IPRs in order to facilitate the invention of technologies that are appropriate to demand in the former region.

The two papers mentioned above employ a static partial-equilibrium framework. Relatively few papers have modeled the dynamic effects of IPRs and growth in a general- equilibrium framework. Helpman(1993) models IPRs, innovation, and economic growth as an interaction between an innovative North and an imitative South. He finds that stronger IPRs protection will decrease Southern imitation and increase Northern innovation in the short run as the profitability of innovation increases. In the long run, however, the rate of innovation actually falls because the North produces more old- technology goods, which takes away resources from innovation. In Helpman's model, innovation is costly and endogenous, but imitation is costless and exogenous. He concludes that Southern welfare declines with tighter IPRs.

Taylor (1994) develops a dynamic, general-equilibrium model to assess the importance of IPRs for trade, growth and technology transfer. He finds that failure by a country to provide patent protection for foreign innovations forces innovators to employ "less than best-practice technologies" and reduces R&D activities and growth worldwide. In his model, both countries innovate and technology transfer is assumed to be costless.

Glass and Saggi (1995) address the effect of tighter IPRs protection in the South on the rate of innovation in the North by allowing both imitation and foreign direct investment (FDI) to serve as simultaneous channels of technology transfer. They show that a strengthening of Southern IPRs, in addition to reducing the rates of innovation and imitation, also increases the risk of imitation faced by multinationals relative to that faced by pure Northern firms and decreases the flow of technology transfer.

In these papers, imitation and FDI are the primary sources through which the South can gain access to the North's advanced technology. Licensing has been largely ignored. This paper focuses on licensing as the means by which the South gets advanced technology. Licensing is conceptually and practically important for a number of reasons. First, when information is not freely transmitted, developing countries often face the problem that the information disclosed in a patent application is not sufficient to lead to profitable imitation (Bagchi et al., 1984). In such situations, it may be necessary to obtain a license before imitation can occur. Second, the product-life-cycle hypothesis (Vernon, 1966) implies a trend toward less market imperfection with product maturity and standardization. In turn, we experience more arm's-length transfers, which is consistent with recent empirical evidence (Mansfield, 1995). Furthermore, government policies in some technology-importing countries prefer licensing as the mode of transfer when it is possible, as opposed to equity investment (Contractor and Sagafi-Nejad, 1981).

To focus on incentives associated with licensing and imitation, this paper builds on the dynamic general-equilibrium model of innovation and imitation developed by Segerstrom (1991). We expand on his framework by emphasizing the effects of IPRs in the Southern economy. We assume that a Northern firm has made a prior decision to license its technology to the South. The important element we incorporate is that once some Southern firms buy advanced technologies, they face the risk of imitation from other Southern firms. Helpman (1993) and Glass and Saggi (1995) use the static Bertrand-equilibrium concept to analyze dynamic product-market competition. This implies that once one Southern firm produces the product, no other identical-cost Southern firms will imitate the same product. In contrast, following Segerstrom (1991), in the current paper mutually beneficial collusion between Southern firms is feasible. Thus, the licensee faces the risk of imitation from other Southern firms and chooses to collude with the imitator after successful imitation transpires. Once the licensed product is imitated, firms will buy more advanced technologies so that they can earn higher profits during the temporary period of dominance.

The effects of stronger IPRs on a Southern firm's incentive to license new technology are two-fold. On the one hand, tighter IPRs decrease the imitation risk faced by firms that first buy advanced technology, allowing them to keep more of their market share and to earn dominant monopoly profits for longer periods. This reduces the incentive to buy more advanced technology. On the other hand, stronger IPRs adversely affect the share of the contract rents that the licensee gains when we assume that some kind of commitment license contract is feasible and that the licensor uses the rent share as a way to deter imitation by the licensee. The responsiveness of this rent share to IPRs is the key parameter in determining impacts on incentives to buy new technologies.

Our dynamic general-equilibrium model of licensing and imitation in the South generates the following main conclusions. First, if the elasticity of rent share that the licensee gets with respect to the strength of IPRs is lower than one (in absolute value), then tighter IPRs decrease the intensity of buying new technology, but its effects on the intensity of imitation, economic growth, and welfare are ambiguous. Second, if the elasticity of rent share that the licensee gets with respect to the degree of IPRs is greater than one (in absolute value), then firmer IPRs decrease the intensity of imitation and reduce economic growth, but have ambiguous effects on the intensity of buying new technology and on welfare.

The remainder of this paper is organized as follows. In Section II we describe the model and derive the steady-state equilibrium. In Section III we study the steady-state comparative statics of IPRs and we conclude in Section IV.

II. The Model

2.1 Consumers

We consider an economy with a continuum of goods indexed by $\omega \in [0,1]$. Each good potentially may be improved a countably infinite number of times, indexed by qualities j = 0, 1, 2, ... The increments to quality are common to all products and exogenously given by a parameter $\lambda > 1$. Each good can be supplied in all discovered quality levels.

Consumers live forever and share identical preferences. The intertemporal utility function for the representative consumer is given by

(1) $$U = \int_0^\infty e^{-\rho t} u(t)dt ,$$

where ρ is the subjective discount rate, and u(t) represents instantaneous utility at time t. We specify

(2) $$u(t) = \int_0^1 \ln\left[\sum_{j=0}^{\infty} \lambda^j d_{jt}(\omega)\right] d\omega$$

where $d_{jt}(\omega)$ denotes consumption of quality j of good ω at time t. Every consumer maximizes discounted utility subject to an intertemporal budget constraint

(3) $$\int_0^\infty e^{-R(t)} E(t)dt = A(0)$$

where R(t) is the cumulative interest factor up to time t: R(t) = $\int_0^t r(s)ds$, A(0) is the value of initial asset holdings plus the present value of factor income, and E(t) is the consumers expenditure flow at time t, given by

(4) $$E(t) = \int_0^1 \sum_{j=0}^{\infty} p_{jt}(\omega)d_{jt}(\omega)d\omega ,$$

and where $p_{jt}(\omega)$ is the price of a product ω of quality j at time t.

The consumer's utility maximization problem can be broken into two stages. First, she optimally allocates lifetime wealth across time, and second, she optimally allocates spending E(t) at each point of time.

Beginning from the second stage, let the consumer maximize the instantaneous utility function in equation (2), given $p_{jt}(\omega)$ and E(t) from equation (4). The Euler equation for this calculus of variations problem yields

(5) $$\sum_{j\in J_t(\omega)} \lambda^j d_{jt}(\omega) = \frac{E(t)\lambda^h}{p_{ht}(\omega)},$$

where $J_t(\omega)$ is the set of available quality levels with the lowest quality-adjusted prices, $p_{jt}(\omega)/\lambda^j$, and $h = h_t(\omega)$ is the highest quality level in $J_t(\omega)$. We assume that, among the firms charging the lowest quality-adjusted prices, consumers buy only from the firms that sell the highest-quality products. Then equation (5) yields the static demand functions

(6) $$d_{jt}(\omega) = \begin{cases} \dfrac{E(t)}{p_{jt}(\omega)} & \textit{for} \quad j = h_t(\omega) \\ 0 & \textit{otherwise.} \end{cases}$$

From equations (5) and (6), we conclude that the composition of spending that maximizes instantaneous utility is attained when the consumer allocates an equal expenditure share to every product ω and when she chooses for every ω the single variety that offers the lowest quality-adjusted price.

For the first stage, after substituting equations (2) and (6) into equation (1), the consumer maximizes equation (1) subject to equation (3). The Euler equation yields

(7) $$\frac{\dot{E}(t)}{E(t)} = r(t) - \rho.$$

In steady-state equilibrium, nominal expenditure E(t) is constant over time, which implies that $r(t) = \rho$.

2.2 Market Structure

We focus our analysis on the Southern economy only. This economy is assumed to have four important characteristics. First, we assume that the Southern country, for whatever reasons, wishes to encourage domestic production of goods and levies a sufficiently high tariff to make exporting to this country prohibitively expensive. Second, we suppose that inward FDI is banned by this Southern country. In fact, in some countries, such as Japan, certain Latin American nations, and socialist nations, government policies traditionally preferred licensing as the transfer mode, wherever possible, over equity investment. One reason is that licensing is likely to be cheaper for the recipient nation in terms of foreign exchange cost (Contractor and Sagafi-Nejad, 1981). Third, we suppose that there is no innovation in the South because its limited knowledge stock makes innovation prohibitively expensive relative to buying technology. Fourth, imitation by "inventing around" the patent is not economically feasible, given only the information revealed in patent. Therefore, licensing becomes the only way by which the Southern firm improves its technology frontier, and imitation only happens after the South buys the technology through licensing.

We distinguish two types of profit-making firms that may operate in equilibrium in the South. The first type is firms (licensees) that buy some state-of-the-art products from, and share rents with, Northern firms. There is a large literature on contracting problems under licensing, but here we simply assume that commitment contracts given certain conditions are feasible. This means that the licensee commits to payments for all future time even if it imitates the licensor's product and the licensor commits to refund part of the payments should it choose to switch licensees.[1] Therefore, it is in the licensor's interest to commit to an exclusive licensing arrangement in order to avoid incurring transfer costs to another licensee and to maintain plant-level scale economies. However, in order to induce the licensee to commit to not imitating, the licensor has to give up some rents to the licensee. Rent-sharing is one of the salient features commonly observed in licensing contracts. Caves, *et al* (1983) make the observation that the licensor earns, on average, only 40% of the rents from the innovation. Under the commitment contract, the licensee will have no incentive to imitate the licensor's product because the expected gain from imitation is same as that under the licensing contract.

The rents that the licensee earns may be used as one way for the licensor to deter imitation.[2] The division of rents between the licensor and licensee depends on many factors, such as each party's bargaining power, the degree of market competition, and government intervention (Contractor, 1981). Here, we solely consider the effect of IPRs on the split for our purposes. If IPRs are tightened in the South, it becomes harder for the licensee to imitate the licensor's product and easier for the licensee to commit not to imitate without demanding a higher share. But if IPRs are lax, the way to commit the licensee not to imitate is to let it share higher rents. The rent share that the licensee gets is a negative function of IPRs. Let δ be the share that the licensee gets. Then $0<\delta<1$ and $\delta = \delta(\kappa)$, $\partial\delta/\partial\kappa < 0$, where κ is the degree of IPRs strength.

The second firm type includes non-licensees that imitate the licensed product. Usually, if there are more than one identical firm in terms of production costs, the static Bertrand-equilibrium concept is used to drive the second firm out of the market. The first firm will price at the same marginal cost, making both firms earn zero economic profits. Accordingly, the second firm will not earn back its imitation cost and thus will not imitate. In contrast, we follow Segerstrom (1991) in assuming that mutually beneficial collusion between Southern firms is feasible. Thus, the licensee faces the risk of imitation from other Southern firms and colludes with the imitator after such imitation.

In this context, we may divide the market into two kinds of groups. The α industries have a single product-quality leader, while the β industries have two collusive product-quality leaders. In the α industries the leader firms use

[1] Horstmann and Markusen (1987) mention such commitment contracts, but assume they are not possible in their model.

[2] Gallini and Wright (1990) show that when imitation by the licensee is possible and when there is asymmetric information, the licensor has to give up some rent to the licensee, and what the licensor gets increases with the imitation cost. Contractor (1980) uses a sample of 102 technology licenses and regression results to support the hypothesis that returns to technology suppliers increase with patent scope.

licensed state-of-the-art technologies to produce higher quality products. In the β industry the licensee and the subsequent imitator collude. Following Sergerstrom (1991), we solve for a steady-state equilibrium with the following properties:

(i) in the α industries, lagging firms engage in imitative R&D but not licensing;

(ii) in the β industries, lagging firms engage in licensing a higher quality of product but do not undertake imitative R&D;

(iii) in each industry, quality leaders do not engage in activities that improve the quality of the product;

(iv) no industry has more than two quality leaders at any moment of time. Thus, imitation only targets the α industries, while acquiring newer technologies through licensing only occurs in β industries. Figure 1 summarizes the market structure.

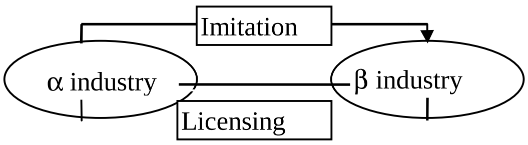


Figure 1: Industrial Structure

2.3 Firms

2.3.1 Research and Development

Licensees spend resources to buy advanced technologies from the North in order to produce higher-quality products. Other Southern firms spend resources to imitate state-of-the-art licensed products. Imitation and licensing entail uncertainty for the individual enterprises. It is reasonable to model technology transfer in a fashion similar to that in modeling innovation. As Teece (1976, p. 100) says, "...the costs involved and the nature of the transfer activity are not too different from the process of R&D itself. Both involve a substantial commitment of resources and a sequence of overlapping stages of activity. Progressing through these stages results in a reduction in uncertainty. The transfer process and the R&D process can both be speeded up if a substantial increment of resources is committed." In his case study of 26 investment projects involving international technology transfer, the total transfer costs were found to range from two to 59 percent of the licensee's total project cost. Further, in the case of licensing, protracted bargaining periods may ensue.

Following Lee and Wilde (1980), we assume that individual research success is a continuous Poisson process. The probability of success during any time interval does not depend upon the resources that have been spent in previous unsuccessful periods. Thus a probability of success during any time interval is proportional to the intensity of effort during that interval. A successful technology transfer means that the transferee plant achieves the proper design and performance specifications. Before that point, considerable resource costs are typically incurred. Among these are the pre-startup training costs and the excess manufacturing costs, which are important in that the difficulty of technology transfer will be closely reflected in them. The excess manufacturing costs reflect the learning and debugging costs during the startup phase before any product may be produced and sold successfully.

The probability of success of licensing depends on the joint efforts of the licensor and licensee. Focusing here on the licensee's side only, the more effort that the licensee puts into licensing, the larger is the probability of success in transferring "know-how." This is unembodied knowledge, or the information that must be acquired if the "hardware" is to be utilized effectively, such as methods of organization and operation, quality control, and other manufacturing procedures. The fact that the licensee spends resources on technology transfer is another reason why the licensor lets the licensee share the rents.

A licensee that engages in licensing at intensity ϕ for an interval of time length dt succeeds in adopting and absorbing the technology with probability ϕdt. This effort requires $a_L\phi$ units of labor per unit of time. The intensity of imitation is C (C stands for "copying") for other Southern firms. Over an interval of time length dt, the probability of success of imitation is Cdt and the effort requires $\kappa a_c C$ units of labor per unit of time. The variable κ represents the degree of a strengthening of IPR protection. A larger κ means that firms must spend more resources for a given imitation intensity to satisfy a stronger uniqueness requirement in the patent law.

We allow free entry and exit into licensing and imitation. Accordingly, the expected gains from R&D for either purpose must not exceed its costs in order to generate finite rates of R&D spending.

First, consider those efforts made by firms to buy, adopt, and absorb the technology for producing higher-quality goods. Successful licensees among those who undertake such efforts attain a stock market value of V_L (L stands for "licensing"). But the licensee must share with the licensor the rents from monopoly production. Each such firm may achieve an expected gain of $\delta(\kappa)V_L\phi dt$, at cost $wa_L\phi dt$, by undertaking R&D at intensity ϕ for an interval dt. Here, we normalize the wage rate in the South to be 1. By the zero-profit condition in licensing, we have

(8) $$\delta(\kappa)V_L \leq a_L \qquad \text{(with equality for } \phi > 0)$$

Second, consider those imitation efforts in the South targeting the licensed state-of-the-art products. The stock value of the imitator is V_C if her imitation is successful. With an intensity of C in imitation for an interval dt, the expected gain is $V_C Cdt$ and the imitation cost is $\kappa a_c Cdt$. Due to free entry in imitation, we have

(9) $$V_C \leq \kappa a_C \qquad \text{(with equality for } C > 0)$$

2.3.2 Production

We have defined V_L and V_C as firm values, which in steady-state must be constant. The value of a firm should be equal to its present value of lifetime profits. Profit streams of firms in the α industries will change when there is successful imitation and profit streams of firms in the β industries will end when other firms buy newer technology.

Consider the incentive of a firm to license a higher-quality technology. A licensee that succeeds in adopting and absorbing a state-of-the-art technology from the North earns the following reward in steady state:

$$(10) \qquad V_L = \int_0^\infty \pi_L e^{-\rho t} e^{-ct} dt + \int_0^\infty V_C e^{-\rho t}(1-e^{-ct})dt = \frac{\pi_L + CV_C}{\rho + C},$$

The first term is the discounted value of the profit stream if imitation from other firms does not occur. Note that e^{-ct} is the probability that there is no imitation up to time t according to the assumptions of the Poisson distribution. The second term is the discounted value of the profit stream when imitation happens at time t. After this time, the licensee colludes with the imitator and earns V_c. We assume symmetric collusion here, although other kinds of collusion are possible.

Once successful in imitation, the imitator earns this reward in steady state:

$$(11) \qquad V_C = \int_0^\infty \pi_C e^{-\rho t} e^{-\phi t} dt = \frac{\pi_C}{\rho + \phi} .$$

We need to know the instantaneous profit earned by each kind of firm. For the licensee firm in a single-leader industry, its closest competitor is the Southern firm that can produce the second-level quality product. Thus, the licensee sets a quality-adjusted price equal to the marginal cost of production. We assume that production exhibits constant returns to scale, which means that one unit of output requires one unit of labor. Thus, $P_L/\lambda = 1$ and $P_L = \lambda$. The licensee will capture the entire market and make sales of E/λ, where E represents aggregate spending. The licensee earns instantaneous profits:

$$(12) \qquad \pi_L = E\,(1-\frac{1}{\lambda}).$$

For firms in two-quality-leaders industries , the quality of their product is still at a one-level lead. The colluding-leader firms price against those Southern firms that are able to produce the second-level products and therefore set $P_C = \lambda$ as well. Their sales will be E/λ and each leader earns instantaneous profits:

(13) $$\pi_C = \frac{1}{2}\ E\ (1-\frac{1}{\lambda}),$$

2.4. Resource Market Clearance

In equilibrium, all resources are fully used for production, licensing, or imitation. We only have one input here, labor. Let labor supply be N, which is exogenously given. Labor-market clearance then requires:

(14) $$\frac{E}{\lambda}(\alpha+\beta) + \phi a_L \beta + \kappa\alpha C a_C = N.$$

The first term is resources employed in production, the second term is resources used in transferring technology, and the third term is resources employed in imitation.

2.5 Steady State Equilibrium

In steady state, measures of products produced in the α and β groups are constant. Recall that α denotes the proportion of industries with one quality leader and β denotes the proportion of industries with two quality leaders. Thus, the flow of production out of the α group must be the same as that into the α group, and the flow of production out of the β group must be the same as that into the β group, as indicated in equation (15).

(15) $$\alpha C dt = \beta\phi dt$$

(16) $$\alpha+\beta = 1$$

From equations (15) and (16), we have $\alpha = \phi/(C+\phi)$ and $\beta = C/(C+\phi)$.

From equations (9), (11), and (13), we can derive the zero-profit condition in imitation:

(17) $$\frac{\frac{1}{2}E(1-\frac{1}{\lambda})}{\rho+\phi} = \kappa a_C,$$

From equations (8) through (13), we can develop the zero-profit condition in licensing technology:

(18) $$\frac{\delta(\kappa)\left[\ E(1-\frac{1}{\lambda}) + C\frac{\frac{1}{2}E(1-\frac{1}{\lambda})}{\rho+\phi}\ \right]}{\rho+C} = a_L,$$

From equations (14), (15), and (16), we have labor-market clearance condition:

(19) $$\frac{E}{\lambda} + (a_L + \kappa a_C)\frac{C\phi}{C+\phi} = N,$$

Combining equations (17) and (19) to write C as a function of ϕ, we have:

$$C_N(\phi) = \frac{(N - \frac{2\kappa a_c \rho}{\lambda - 1})\phi - \frac{2\kappa a_c}{\lambda - 1}\phi^2}{(\frac{2\kappa a_c \rho}{\lambda - 1} - N) + (a_L + \kappa a_c + \frac{2\kappa a_c}{\lambda - 1})\phi}, \quad (20)$$

The above equation gives the intensity of imitation for every given intensity of licensing if both labor-market clearance and the zero-profit condition in imitation are satisfied.

By differentiating $C_N(\phi)$ with respect to ϕ, we find $\frac{\partial C_N(\phi)}{\partial \phi} < 0$, implying that $C_N(\phi)$ is negatively sloped. The intuition behind this is straightforward. When C increases, imitation will use more labor. But because the labor supply is exogenously fixed, the labor that can be used in transferring technology will decrease, and ϕ must decrease as well.

If we combine equations (17) and (18), we can get another equation for C in terms of ϕ:

$$C_\phi(\phi) = \frac{(2\delta(\kappa)\kappa a_c - a_L)\rho + 2\delta(\kappa)\kappa a_c \phi}{a_L - \delta(\kappa)\kappa a_c} \quad (21)$$

The above equation gives the intensity of imitation for every given intensity of licensing if zero-profit conditions in imitation and transferring technology are satisfied.

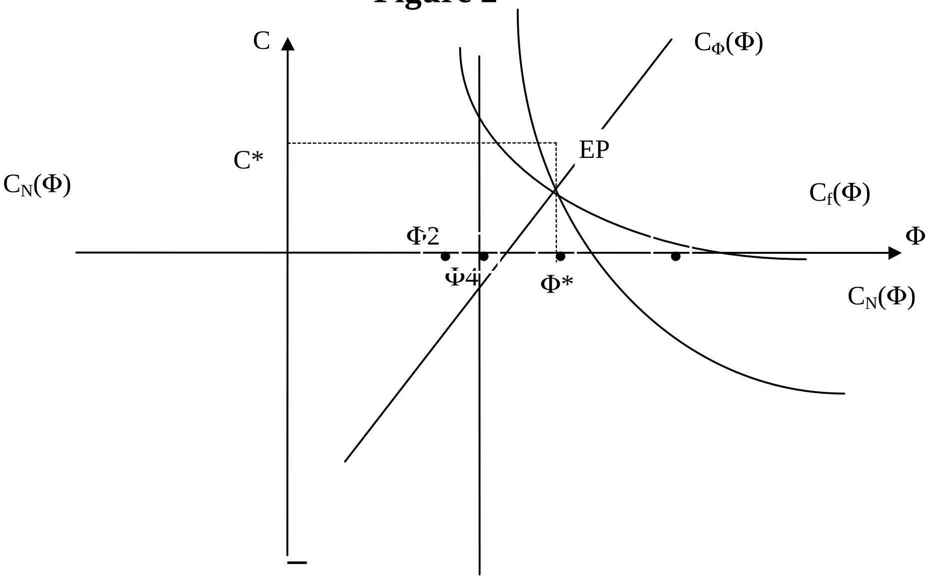
In order to determine the slope of $C_\phi(\phi)$, we must first discuss the sign of the term a_L-$\delta(\kappa)\kappa a_C$. If $a_L > \delta(\kappa)\kappa a_C$, then V_L must be greater than V_C by equations (8) and (9) in order to have both imitation and licensing in the equilibrium. If $V_L < V_C$ and $a_L > \delta(\kappa)\kappa a_C$, then the expected value of licensing is less than the expected value of imitation while the cost of licensing exceeds the cost of imitation. Therefore, no one will spend resources to license advanced technology. Instead, everyone will wait to imitate but since there is no licensed technology, there is no imitation either. In fact, we find that V_L is definitely greater than V_C from equations (10)-(13). Therefore, we have $a_L > \delta(\kappa)\kappa a_{C.}$

Because $a_L > \delta(\kappa)\kappa a_C$, then $C_\phi(\phi)$ is positively sloped. The intuition behind this result is that if C increases, the single leader will earn dominant monopoly profits for a shorter period. By the zero-profit condition in licensing, the licensee should earn higher instantaneous monopoly profits. If the dominant profits are higher then the collusive profits are higher also. By virtue of the zero-profit condition in imitation, the imitator must earn the collusive profits for a shorter period and ϕ must increase.

We draw $C_N(\phi)$ and $C_\phi(\phi)$ in Figure 2. In order to have positive amounts of both imitation and licensing in the equilibrium, we make the assumption that

$N > \mathrm{Max}(\frac{2\kappa a_c \rho}{\lambda - 1}, \frac{a_L \rho}{(\lambda - 1)\delta})$. This assumption ensures that $\phi_4 > 0$ and that point ϕ_3 lies to the right of point ϕ_2. If this were not true, we would have negative imitation in equilibrium. In Figure 2, ϕ_2 is the point at which $C_\phi(\phi) = 0$ and ϕ_3 is the point at which $C_N(\phi) = 0$. Point ϕ_4 denotes the level of licensing at which $C_N(\phi)$ becomes infinite. The points C^* and ϕ^* are the equilibrium intensities of imitation and innovation.

Figure 2



2.6 The aggregate rate of licensing and imitation

Define the aggregate rate of licensing as $f = \phi\beta$, and the aggregate rate of imitation as $m = \alpha C$. Thus, $f = m = \frac{C\phi}{C + \phi}$. If either C or ϕ increases, the other held constant, f and m will increase also.

2.7 Welfare

If we substitute $P = \lambda$ and equation (5) back into the instantaneous utility function (2), we find that

(22) $$u(t) = \ln E - \ln \lambda + \int_0^1 \ln \lambda^h d\omega .$$

According to the properties of Poisson distribution, we can get

(23) $$u(t) = \ln E - \ln \lambda + f\, t \ln \lambda$$

If we substitute expression (23) into equation (1), we derive

(24) $$U_0 = \frac{1}{\rho}[\ln(\frac{E}{\lambda}) + \frac{f}{\rho}]$$

III. Steady-State Comparative Statics

Now we are ready to study the effects of tightened IPRs on the intensity of licensing, the intensity of imitation, the aggregate rate of buying new technology (the Southern growth rate), and economic welfare.

First, if κ increases, which means there are stronger IPRs in the South, the $C_\phi(\phi)$ curve shifts. But the direction of this shift depends on the elasticity of the licensee's rent share with respect to the degree of IPRs protection. We have Proposition I:

Proposition I:

Define $\sigma = \frac{\partial \delta}{\partial \kappa}\frac{\kappa}{\delta}$ as the elasticity of the licensee's rent share with respect to the degree of IPR protection. If $|\sigma| < 1$, then $\frac{\partial C_\phi(\phi)}{\partial \kappa} > 0$ and $C_\phi(\phi)$ will shift up. If $|\sigma| > 1$, then $\frac{\partial C_\phi(\phi)}{\partial \kappa} <$ 0 and $C_\phi(\phi)$ will shift down (See Appendix A).

Recall that $C_\phi(\phi)$ represents the level of C for every given ϕ when the zero-profit conditions in both licensing and imitation are satisfied. The variable κ appears on the right-hand side of the zero-profit condition in imitation. It also appears implicitly in the zero-profit condition in buying technology through parameter δ, because δ is a function of κ. When σ (in absolute value) is less than 1, which means that the rent share that the licensee gets is inelastic to the degree of IPRs protection, the effect of a higher κ on the cost of imitation dominates its effect on the licensee's rent share and $C_\phi(\phi)$ shifts upward. In contrast, when σ (in absolute value) is greater than 1, which means that the rent share that the licensee gets is elastic to the degree of IPRs protection, the effect of a higher κ on the rent share dominates, and $C_\phi(\phi)$ shifts downward (see equation (21) and Appendix A).

The effect of a rise in κ on the $C_N(\phi)$curve is unambiguous. It will shift down when there is tighter intellectual property rights, because $\frac{\partial C_N(\phi)}{\partial \kappa} < 0$.

Combining the effects of tighter IPRs on both $C_\phi(\phi)$ and $C_N(\phi)$, we get Proposition II and Proposition III.

Proposition II:

If IPRs are strengthened and the (absolute) response of the rent share is inelastic, the intensity of buying advanced technology (ϕ) will decrease. The effects on intensity of imitation (C), economic welfare, and the aggregate rate of licensing and imitation are ambiguous.

The intuition behind Proposition II is as follows. When κ increases, the cost of imitation increases, which is the dominant effect in this case. By the zero-profit condition in imitation, the imitator must earn collusive profits for a longer period, which implies that the intensity of buying newer technology must decrease. But the effect of tighter IPRs on C is ambiguous because, on the one hand, when ϕ decreases, the zero-profit condition in buying new technology would mandate a decrease in the intensity of imitation. On the other hand, labor-market clearance requires that the intensity of imitation must increase.

To study impacts on the aggregate rate of licensing or imitation (f = m), we draw the iso-growth curve $C_f(\phi)$ through equilibrium point EP in Figure 2. This curve represents all possible combinations of C and ϕ that give the same level of f. Note that a shift of $C_f(\phi)$ to the northeast corresponds to a higher f. From Appendix B, we know that $C_f(\phi)$ is negatively sloped and flatter than $C_N(\phi)$. Thus, we find that the effect of stronger IPRs on f is ambiguous because whether f increases or decreases depends on whether the new equilibrium point lies above or below the original $C_f(\phi)$ curve. Because economic welfare depends on E and f, the effect of tighter IPRs on welfare is ambiguous as well.

Our next proposition considers the case of an elastic response in rent share.

Proposition III:

> If IPRs are tightened and the (absolute) rent-share response is elastic, the intensity of imitation (C) will decrease and the aggregate rate of licensing and imitation (f) will decrease. But the effect of tighter IPRs on the intensity of buying new technology (ϕ) and welfare will be ambiguous.

The intuition behind proposition III is as follows. On the one hand, when κ increases, the cost of imitation increases. By the zero-profit condition in imitation, the intensity of licensing new technologies must decrease to make sure that the imitator earns collusive profits for a longer period. On the other hand, when κ increases, the rent share that the licensee gains decreases. By the zero-profit condition in licensing, this implies that the intensity of imitation must decrease so that the licensee earns a dominant profit for a longer period, but by the labor-market clearance condition, the intensity of licensing must increase. Therefore, the intensity of imitation decreases and the intensity of licensing could increase or decrease, depending on parameter values.

The aggregate rate of licensing and imitation will fall, because the new equilibrium point must lie below the old one (EP) and because the iso-growth curve $C_f(\phi)$ is flatter than $C_N(\phi)$.

IV. Numerical Results

We undertake a numerical simulation of the model to determine conditions under which the various outcomes transpire. Numerical results are capable of supporting both Proposition II and Proposition III. Consider four configurations of parameter values.

Case I: $\rho = 0.08$, $N = 0.9$, $\lambda = 4$, $a_l = 1$, and $a_C = 0.7$.

Table 1

	$\kappa = 1, \delta = 0.6$	$\|\sigma\| < 1$ $\kappa = 1.1, \delta = 0.58$	$\|\sigma\| > 1$ $\kappa = 1.1, \delta = 0.5$
C	0.833	0.852 (↑)	0.697 (↓)
ϕ	0.590	0.537 (↓)	0.581 (↓)
f	0.345	0.329(↓)	0.317 (↓)
U	39.444	37.111 (↓)	35.992 (↓)

For Case I, we find that:

(a) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.58 ($|\sigma| < 1$), then C increases and ϕ decreases, while f and U decrease;

(b) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.5 ($|\sigma| > 1$), both ϕ and C decrease and f and U also decrease.

Case II: $\rho = 0.08$, $N = 0.7$, $\lambda = 4$, $a_l = 1$, and $a_C = 0.3$.

Table 2

	$\kappa = 1, \delta = 0.6$	$\|\sigma\| < 1$ $\kappa = 1.1, \delta = 0.58$	$\|\sigma\| > 1$ $\kappa = 1.1, \delta = 0.5$
C	0.471	0.466 (↓)	0.418 (↓)
ϕ	1.215	1.114 (↓)	1.220 (↑)
f	0.339	0.329 (↓)	0.311 (↓)
U	36.124	34.664 (↓)	32.911 (↓)

For Case II, we find that:

(c) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.58 ($|\sigma| < 1$), both C and ϕ decrease and f and U also decrease;

(d) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.5 ($|\sigma| > 1$), ϕ increases and C decreases, while both f and U decrease.

If we compare (a) and (c), in which $|\sigma| < 1$ for different parameter values, ϕ falls, but C could rise or fall, which supports Proposition II. If we compare (b) and (d), in which $|\sigma| > 1$ for different parameter values, C decreases, but ϕ could increase or decrease, which supports Proposition III. But f and U both decrease in each case.

Case III: ρ = 0.2, N = 0.9, λ = 10, a_l = 1, and a_C =0.7.

Table 3

	κ = 1, δ = 0.6	|σ| < 1 κ = 1.1, δ = 0.58	|σ| >1 κ = 1.1, δ = 0.4
C	1.049	1.080 (↑)	0.708 (↓)
ϕ	0.762	0.693(↓)	0.920 (↑)
f	0.441	0.422 (↓)	0.400 (↓)
U	1.538	1.161 (↓)	1.745 (↑)

For Case III, we find that:

(e) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.58 (|σ|<1), C rises and ϕ falls, while both f and U go down;

(f) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.4 (|σ| > 1), ϕ increases, C decreases, f decreases, and U increases.

Case IV: ρ = 0.2, N = 0.7, λ = 10, a_l = 1, and a_C =0.3.

Table 4

	κ = 1, δ = 0.6	|σ| < 1 κ = 1.1, δ = 0.58	|σ| >1 κ = 1.1, δ = 0.4
C	0.594	0.590 (↓)	0.486 (↓)
ϕ	1.708	1.596(↓)	2.155 (↑)
f	0.441	0.429 (↓)	0.396 (↓)
U	0.705	0.508 (↓)	1.131 (↑)

For Case IV, we find that:

(g) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.58 (|σ| < 1), both C and ϕ fall and f and U also are reduced;

(h) when κ increases from 1 to 1.1 and δ decreases from 0.6 to 0.4 (|σ| > 1), ϕ rises, C falls, f falls, and U goes up.

If we compare (e) and (g), in which |σ| < 1 for different parameter values, ϕ falls but C could increase or decrease, which supports Proposition II. When|σ| > 1, in cases (f) and (h), ϕ rises, C falls, f decreases, and U increases.

Also, if we compare cases (b) and (f), and cases (d) and (h), we find that for different ρ and λ values, utility could increase or decrease due to an rise in κ when $|\sigma| > 1$, which supports Proposition III. If ρ (the subjective discount rate) and λ (the increment to quality due to innovation) are sufficiently large, and the rent share that the licensee gets is elastic to the degree of IPRs protection, then South's welfare could increase due to tighter IPRs.

V Conclusion

This paper studies the role of intellectual property rights (IPRs) in helping developing countries gain access to knowledge on the global frontier by focusing on licensing as the means by which the South gets advanced technology. The licensee faces the risk of imitation from other Southern firms and chooses to collude with the imitator after successful imitation transpires. Once the licensed product is imitated, firms will buy more advanced technologies in order to earn higher profits during the temporary period of dominance allowed by licensing. This improves the technology frontier of the South. Through increasing the cost of imitation and decreasing the rent share that the licensee gains, tighter IPRs affect Southern firms' incentives to buy new technology and to imitate.

Our results are different from those in Helpman(1993) and Glass and Saggi(1995). Helpman shows that in the long run the South will suffer from stronger IPRs, while Glass and Saggi show that strengthening IPRs will decrease the flow of technology transferred to the South. Although our model is not directly comparable with theirs, we show that tighter IPRs may or may not decrease the rate of buying new technology by the South, and that Southern welfare may increase or decrease because of stronger protection of IPRs.

Our next step will be to extend this framework to a North-South trade model by modeling more formally the effect of IPRs on the rent share between the licensor and licensee and by endogenizing the determination of the rent share.

Appendix A

Proof of Proposition I.

From Equation (21), differentiate C with respect to ϕ, we have

$$(1)' \qquad \frac{\partial C_{\phi}(\phi)}{\partial \kappa} = \frac{1}{(a_L - \delta(\kappa)\kappa a_C)^2}\left[a_C a_L(\rho + 2\phi)(\delta(\kappa) + \kappa\delta'(\kappa))\right],$$

From (1)', we can get Proposition I.

Appendix B

First, derive the slope for the iso-growth curve. By total differentiating f $= \frac{C\phi}{C+\phi}$, we have

$$(3)' \qquad \frac{\partial C_f(\phi)}{\partial \phi} = -\frac{C^2}{\phi^2},$$

Second, from Equation (20), differentiating C with respect to ϕ, we have

$$(4)' \qquad \frac{\partial C_N(\phi)}{\partial \kappa} = -\frac{C^2}{\phi^2} \cdot \frac{\left|(N - \frac{2\kappa a_C \rho}{\lambda - 1}) - \frac{2\kappa a_C \phi}{\lambda - 1}\right|^2 + \phi^2 \frac{2\kappa a_C}{\lambda - 1}(a_L + \kappa a_C)}{\left[(N - \frac{2\kappa a_C \rho}{\lambda - 1}) - \frac{2\kappa a_C \phi}{\lambda - 1}\right]^2}$$

Combine Equations (3)' and (4)', we find that $C_N(\phi)$ is steeper than $C_f(\phi)$.

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