

# Intellectual Property Rights, Licensing, and Innovation

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## Abstract

There is considerable debate in economics literature on whether a decision by developing countries to strengthen their protection of intellectual property rights (IPRs) will increase or reduce their access to modern technologies invented by industrial countries. This access can be achieved through technology transfer of various kinds, including foreign direct investment and licensing. Licensing is the focus of this paper.

To the extent that inventing firms choose to act more monopolistically and offer fewer technologies on the market, stronger IPRs could reduce international technology flows. However, to the extent that IPRs raise the returns to innovation and licensing, these flows would expand. In theory, the outcome depends on how IPRs affect several variables—the costs of, and returns to, international licensing; the wage advantage of workers in poor countries; the innovation process in industrial countries; and the amount of labor available for innovation and production.

Yang and Maskus develop a theoretical model in which firms in the North (industrial countries) innovate products of higher quality levels and decide whether to produce in the North or transfer production rights to the South (developing countries) through licensing. Different quality levels of each product are sold in equilibrium because of differences in consumers' willingness-to-pay for quality improvements. Contracting problems exist because the inventors in the North must indicate to licensees in the South whether their product is of higher or lower quality and also prevent the licensees from copying the technology. So, constraints in the model

ensure that the equilibrium flow of licensing higher-quality goods meets these objectives. When the South strengthens its patent rights, copying by licensees is made costlier but the returns to licensing are increased. This change affects the dynamic decisions regarding innovation and technology transfer, which could rise or fall depending on market parameters, including the labor available for research and production.

Results from the model show that the net effects depend on the balance between profits made by the Northern licensor and lower labor costs in the South. If the size of the labor force used in Northern innovation compared with that used in producing goods in both the North and South is sufficiently small (a condition that accords with reality), stronger IPRs in the South would lead to more licensing and innovation. This change would also increase the Southern wage relative to the Northern wage. So, in this model a decision by developing countries to increase their patent rights would expand global innovation and increase technology transfer. This result is consistent with recent empirical evidence.

It should be noted that while the results suggest that international agreements to strengthen IPRs should expand global innovation and technology transfer through licensing, the model cannot be used for welfare analysis. Thus, while the developing countries enjoy more inward licensing, the cost per license could be higher, and prices could also rise, with an unclear overall effect on economic well-being.

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This paper—a product of Trade, Development Research Group—is part of a larger effort in the group to assess the impact of intellectual property rights on economic development. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Paulina Flewitt, room MC3-333, telephone 202-473-2724, fax 202-522-1159, email address [pflewitt@worldbank.org](mailto:pflewitt@worldbank.org). Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at [keith.maskus@colorado.edu](mailto:keith.maskus@colorado.edu) or [lynn.yang@worldnet.att.net](mailto:lynn.yang@worldnet.att.net). February 2003. (34 pages)

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**Intellectual Property Rights, Licensing, and Innovation**

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## 1. Introduction

Intellectual property rights (IPRs) remain an active subject in international policy debates. Technology exporters in developed countries argue that stronger IPRs are needed in developing countries in order to provide better incentives for innovation and international technology transfer. The recent introduction of global minimum standards for IPRs, through the Agreement on Trade-Related Intellectual Property Rights (TRIPS) in the World Trade Organization, raises many questions about the relationships among IPRs, technology transfer, and economic growth.

This paper studies the effects of IPRs on innovation and technology transfer in a North-South dynamic general-equilibrium, product-cycle model with vertically differentiated products. Compared to the previous literature, in which imitation and foreign direct investment (FDI) are the channels of technology transfer, this model focuses on licensing as the means by which the South acquires advanced technology from the North. Licensing embodies features that are missing in these other channels, namely costs of contracting at arm's-length between innovators and licensees. These costs interact with IPRs in important ways. In particular, we argue that strengthened patent rights could reduce such costs, raising returns to licensing. Indeed, according to standard internalization theory, relatively weak IPRs protection may cause MNEs to transfer technological knowledge through FDI, because there is a risk of dissipation with licensing (Rugman, 1986). Therefore, strong IPRs tend to favor licensing because a system of IPRs is necessary to the enforcement of the licensing contract (Ferrantino, 1993; Arora, 1996; Maskus, 1998).

In practice, international licensing through arm's-length contracts and joint ventures have taken on increasing importance in recent years (Maskus and Yang, 2001). For example, as a

major technology exporting country, US receipts of unaffiliated royalties and license fees were 21% of total royalties and license fees received from all the countries in the world in 1995.

Imperfections in the market for licensing, such as information asymmetry, uncertainty, imitation risk, and transaction costs, have made incorporating licensing into general-equilibrium models difficult (Caves, *et. al*, 1983). This paper provides one means of capturing how IPRs affect international technology transfer through licensing<sup>1</sup>. We focus on two pervasive problems in licensing: asymmetric information and imitation risk. The licensor has an incentive to convey misinformation about the true quality level of its technology and is unwilling to transfer its innovation without a payment or commitment by the licensee not to imitate. In the model, two different quality levels (high and low) of each product are sold in equilibrium due to differences in the willingness to pay of consumers for quality improvements. Multiple quality levels permit asymmetric information regarding true quality levels in setting licensing contracts.

With asymmetric information and imitation risk, the licensor is faced with the problem of designing a contractual form that signals its technological advantage while discouraging imitation (Gallini and Wright 1990). In consequence, the low-quality licensor can extract full monopoly rents from the licensee using a fixed fee. However, the high-quality licensor must share rents with the licensee due to a combination of asymmetric information and the risk of imitation. We extend this notion to show that the licensor share increases with the degree of IPRs protection in the South. By endogenizing this rent share between the licensor and the licensee, we find that stronger IPRs allow lower-cost signaling of quality levels and generate more licensing.

With two quality levels sold in equilibrium, production of low-quality goods always takes place in the South through licensing in order to take advantage of lower labor costs. However,

production of high-quality goods may either remain in the North or migrate to the South through licensing. The Northern innovative firm first chooses the intensity of effort it devotes to innovation. Once innovation is successful, the firm balances savings from lower wage costs with rent sharing in choosing whether to license.

Results from the model show that the effects of IPRs in the South on innovation and licensing depend on the balance between the rents given up through licensing and lower labor costs in the South. Stronger IPRs award the high-quality licensor with a higher rent share, resulting in greater returns from licensing and innovation. Whether this change generates additional innovation and licensing in general equilibrium depends on resource constraints. Our key result is that these activities would rise if the labor force used in Northern innovation relative to that used in global production of both types of goods is sufficiently small. This condition seems consistent with reality, in that the share of research and development in gross domestic product is far smaller than the corresponding share of manufacturing output, even in developed economies.

This conclusion supports the intuition that stronger global protection of the fruits of R&D should encourage innovation. It is more optimistic about the impact of the TRIPS agreement than were the findings of prior literature. For example, Helpman (1993) found that with stronger IPRs protection the rate of innovation would fall in the long run because the North would produce more goods, taking away resources from innovation. Glass and Saggi (2002) showed similarly that a strengthening of IPRs in the South would reduce the rate of innovation because stronger IPRs would guarantee the market share of innovators. In turn, more labor would be used to produce goods in the North, providing less labor for innovation. Further, the flow and extent of FDI would decrease with a strengthening of Southern IPRs due to the increased imitation risk

faced by multinationals relative to Northern firms. However, Lai (1998) found that the effects of strengthening IPRs depend crucially on the channel of technology transfer from the North to the South. Stronger IPRs in the South would raise the rates of technology transfer and innovation if FDI is the channel of technology transfer but would have opposite effects if production is transferred through imitation.

Our focus on licensing points out that this channel of information transfer would respond positively to stronger patent rights by virtue of the ability of those rights to reduce the severity of imperfections in the licensing market. In an earlier paper (Yang and Maskus, 2001a) we found conditions under which strengthened industrial property would increase licensing and innovation, though without the contracting distortions modeled here. Indeed, limited econometric evidence suggests that, other things equal, U.S. firms license more to nations with stronger IPRs (Ferrantino, 1993; Yang and Maskus, 2001b).

The paper proceeds as follows. In Section 2 we set up a general-equilibrium model with licensing as the channel of technology transfer and with two quality levels sold in equilibrium. In Section 3 we derive solutions for steady-state equilibrium and investigate the effects of a Southern strengthening of IPRs. Concluding remarks are provided in Section 4.

## **2. The Model**

### *2.1 Consumers*

The consumption side of the model is closely similar to that in Glass (1997), so we only highlight its features. Consider an economy with a continuum of goods indexed by  $j \in [0, 1]$ . Each good potentially can be improved a countably infinite number of times, indexed by qualities



$m = 0, 1, 2, \dots$ . The increments to quality are common to all products and exogenously given by a parameter  $\lambda > 1$ . Each good may be supplied in all discovered quality levels.

There are two types of consumers, who differ in their willingness to pay for quality improvements. They are indexed by  $\omega \in \{A, B\}$ . High-type consumers (B) value the same quality improvement  $\lambda$  more than low-type consumer (A):  $\lambda^B > \lambda^A > 1$ .

Each type of consumer lives forever and shares identical preference within her group. The intertemporal utility function for the representative consumer of type  $\omega$  is given by

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

where  $\rho$  is the subjective discount rate, and  $u^\omega(t)$  represents instantaneous utility at time  $t$ . We specify instantaneous utility as

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

where  $d_{mt}^\omega(j)$  denotes consumption by type  $\omega$  consumer of quality  $m$  of good  $j$  at time  $t$ .

Every  $\omega$ -type consumer maximizes discounted utility subject to an intertemporal budget constraint

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

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

$$E^\omega(t) = \int_0^1 \sum_{m=0}^{\infty} p_{mt}(j) d_{mt}^\omega(j) dj \quad (4)$$

where  $p_{mt}(j)$  is the price of a product  $j$  of quality  $m$  at time  $t$ . Define aggregate spending by all consumers as  $E = E^A + E^B$ . Let  $f^\omega$  describe the exogenously given percentage of world income distributed to each type of consumer:  $f^B$  is distributed to high-type consumers, while  $f^A = 1 - f^B$  goes to low-type consumers. For simplicity, the same distribution of income applies to both countries.

The consumer's utility maximization problem can be broken into two stages. In the first stage, she optimally allocates lifetime wealth across time. The consumer evenly spreads lifetime spending across time and the interest rate at each point of time equals the subjective discount rate:  $r(t) = \rho$ . In the second stage, she optimally allocates spending  $E(t)$  at each point of time. The composition of spending that maximizes instantaneous utility is attained when the consumer allocates an equal expenditure share to every product  $j$  and when she chooses for every  $j$  the single variety that offers the lowest quality-adjusted price. If a higher quality good has the same quality-adjusted price as a lower quality good, consumers prefer the former.

Due to heterogeneity in consumers' willingness to pay for quality improvement, more than one quality level is sold in equilibrium. While all consumers agree that quality level  $m + 1$  is better than quality level  $m$ , A-type and B-type consumers disagree over how much better. For a range of prices, the high-type consumer selects quality  $m + 1$ , and the low-type consumer selects quality  $m$ . In Appendix A we show that equilibrium with vertical quality differentiation occurs provided a sufficient percentage of income is in the hands of high-type consumers. Firms choose prices that cause the high-type consumers to self-select into buying the high-quality level, whereas low-type consumers buy the low-quality level. The existence of two quality levels in equilibrium allows consideration of information asymmetry in licensing.

## *2.2 Market Structure*

North and South are different in their abilities to conduct “state-of-the-art” research and development (R&D). The North is more productive in R&D and all innovation takes place there in a steady-state equilibrium. In the absence of licensing, the South does not have the technology to produce either of the top two quality levels by itself. We assume that imitation by direct inspection of imported goods is too costly to be economically feasible. We assume further that the activities of “inventing around” patents and reverse engineering are not economically feasible given only the information revealed in a patent application. Thus, licensing is the only means by which the South can acquire Northern top technologies. Licensed technologies may be imitated at some cost.

There are many firms in the North. Because two quality levels are sold in equilibrium, we define firms that had innovated the current highest quality level of any good as “leaders”, and other firms as “followers”. Following Grossman and Helpman (1991a), we assume that a Northern producer with an existing technology lead will not conduct research to improve the quality of its own product. Therefore, R&D for product improvement is conducted by followers.

In deciding whether to license technology to the South, the Northern licensor is challenged with the problem of designing a licensing contract that maximizes profits given market imperfections in licensing. Markusen (1995) reviews such imperfections, including information asymmetry, the non-excludability property of new knowledge, imitation risk, transfer cost, and moral hazard.

Among these, we consider the problems of information asymmetry and imitation risk when writing licensing contracts. Licensors know the true quality of the product, but licensees recognize that the low-quality licensor may pretend to have a high-quality product. Further, the

licensee could imitate the technology after licensing it in the hope of earning all the monopoly rents for itself. In this case, the licensor must choose a contractual form that signals the informational advantage while discouraging imitation.

High-quality licensors wish to prevent low-quality licensors from misrepresenting their products. Thus, they must signal their true high quality to allow the licensee to distinguish it from lower-quality products. At the same time, they must discourage imitation by licensees after the technology is transferred. In our model, the solution to this maximization problem requires giving up some rents to the licensee. This rent share operates as a quality signal and also makes the licensee unwilling to imitate. The licensor's rent share is a positive function of imitation cost, as shown in detail later. Thus, if the South adopts stronger IPRs the imitation cost of the licensee would increase and the licensor would get more rents. In consequence, stronger IPRs allow lower-cost signaling of quality levels.

The high-quality licensor's optimal contract prevents the low-quality licensor from pretending to be a high-quality licensor. The low-quality licensor extracts full rents from its licensee by offering a contract with the single instrument of a fixed fee equal to those rents. Because this licensor extracts full rents at the beginning, the licensee has no incentive to imitate. Imitation would yield zero profit in production but would require expenditure of resources, making net profits negative.

In this framework, production of low-quality products always takes place in the South through licensing, which is more profitable for the licensors due to lower labor costs. The property that low-quality technologies are instantaneously licensed to the South eliminates any role for obsolescent (that is, third-level) technologies in determining the licensing contract. However, production of high-quality products may occur either in the North or the South.

Northern firms first choose the intensity of innovation. If the innovation is successful, they would choose whether to license their technology to the South. Thus, innovative firms must strike a balance between lower labor costs in the South and the rents given up through licensing.

There are two possible market types for each good. The first is a high-quality licensed technology market (H), in which both high-quality and low-quality goods are produced in the South through licensing. The second is a low-quality licensed technology market (L), in which high-quality goods are produced in the North and low-quality goods are produced in the South through licensing. Innovation targets both markets. When innovation aimed at the H market is successful the market becomes an L. The newly innovated highest quality is produced in the North. The formerly high-quality good becomes the low-quality good and remains in production in the South. For its part, when innovation targeting the L market is successful it becomes a new L, with the original high-quality good converting to the low-quality good, which is instantaneously licensed to the South.

We model licensing of newly innovated, highest-quality products as a random process. When successful licensing of a high-quality product occurs, both quality levels will be produced in the South and the L market becomes an H. Imitation by the licensee is modeled through its effect on the rent share between the licensing partners, as noted below.

We preclude the possibility of imitation of licensed technologies by other Southern firms. Following Grossman and Helpman (1991a), we assume that if such imitation occurred, the licensee would set price to equal the imitator's marginal cost. Neither firm would earn positive profits in the resulting Bertrand competition. Because there are positive imitation costs, this situation never arises in equilibrium. We summarize the basic market structure in Figure 1.

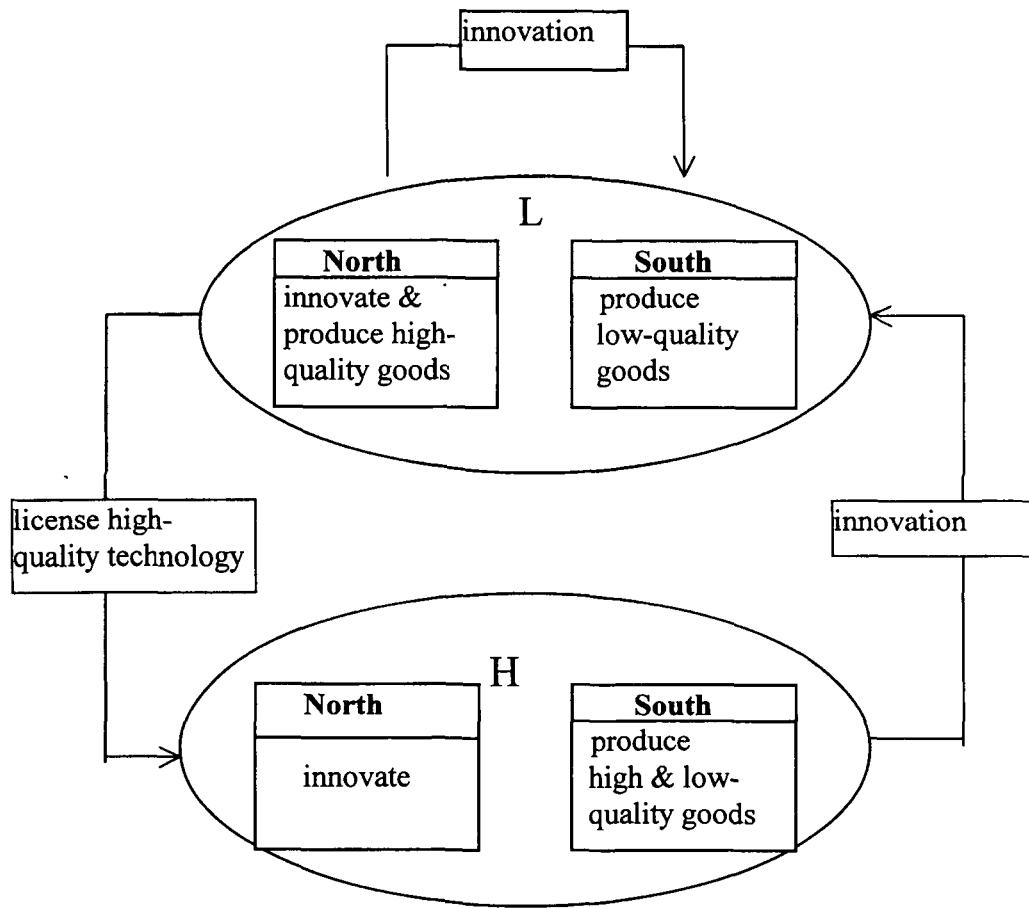


Figure 1. Market Structure

### 2.3 Firms

#### Innovation and Licensing

Firms spend resources to innovate “state-of-the-art” products. Following Grossman and Helpman (1991b), 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 firm that engages in innovation at intensity  $\eta$  for an interval of time length  $dt$  succeeds with probability  $\eta dt$ . This effort requires  $a \cdot \eta$  units of labor per unit of time. The variable  $\eta$ , which is endogenous, is the Poisson arrival rate at which “state of the art” technology will be innovated in the next instant.

After a firm succeeds in innovating a technology yielding a higher-quality product, it chooses the location of production and whether to license abroad. We assume constant marginal production costs, equal to the Southern wage rate, in order to focus on the case of exclusive licensing. If there were increasing marginal costs in Southern production, it could be in the licensor’s interest to have nonexclusive licensing in order to minimize cost.

The licensing decision is also a random process. Assume that the duration  $\tau$  between the time of innovation and the time of licensing has an exponential distribution with cumulative density  $\Pr(\tau \leq t) = 1 - e^{-\iota t}$ , where  $\iota$  is the endogenous Poisson arrival rate at which the high-quality technology will be licensed to the South in the next instant. The probability that licensing takes place in the time interval  $(t, t + \Delta t)$  is given by  $\iota \Delta t$ , where the good is produced in the North after innovation up to time  $t$ .

The licensor of a high-quality technology faces imitation risk from the licensee. There is no uncertainty involving the imitation process, but imitation costs resources. These costs depend positively on the degree of IPRs protection in the South. Tighter IPRs make it harder to make a noninfringing, perfect substitute.

With this background, consider the innovation process. Successful innovators attain a market value of  $V_L^1$ , where the subscript stands for market group, and the superscript 1 stands for “top firm” in that market (the superscript 2 stands for “trailing firm” in that market). Each firm may achieve an expected gain of  $V_L^1 \eta dt$ , at cost  $wa \eta dt$ , by undertaking R&D at intensity  $\eta$  for an

interval  $dt$ . The Northern wage rate is  $w$ . By the zero-profit condition from free entry and exit in innovation, we have

$$V_L^l = wa, \quad \eta > 0 \quad (5)$$

Next, consider the decision of Northern leading firms to license. All such firms are symmetric. At any date, the equilibrium value of  $\iota$  is that which leaves all innovator firms indifferent between licensing and continuing production in the North. The present discounted value (PDV) of profits from licensing is a decreasing function of  $\iota$ . This follows because an increase in  $\iota$  implies that more production is transferred to the South, raising the demand for Southern labor. As the Southern wage increases relative to  $w$ , profits from licensing decrease. Similarly, the PDV of profits from continuing production in the North is an increasing function of  $\iota$ .

Thus, if  $\iota$  is below its equilibrium value, profits from licensing are higher than those from Northern production. More Northern firms transfer their production to the South and  $\iota$  rises. If  $\iota$  is above its equilibrium value, there are gains from moving production back to the North and  $\iota$  falls. It follows that in equilibrium, the expected value from licensing is equal to the expected value from continuing production in the North. The equilibrium licensing condition is

$$V_H^l = V_L^l, \quad \iota > 0 \quad (6)$$

where  $V_H^l$  is expected lifetime rents from licensing<sup>2</sup>. It differs from full rents  $V_H^f$  when there is asymmetric information and imitation risk, as shown below. The term  $V_L^l$  is the expected value of a leading Northern firm if it continues production in the North.



## Production and Contracting

In a steady-state equilibrium, each firm's value is constant and equals the present value of its lifetime profits. Firms in a low-quality licensing market (L) face the risk of innovation and the risk of high-quality technology being licensed to the South. When either of these events happens, firm values change.

The steady-state value of the top firm in the low-quality licensing market is given by

$$V_L^1 = \frac{\pi_L^1 + \eta V_L^2 + \iota V_H^1}{(\rho + \eta + \iota)} \quad (7)$$

where  $\pi_L^1$  is the firm's instantaneous profit when innovation and licensing do not occur.<sup>3</sup> If innovation happens the top firm in the L market would become the trailing firm in the L market and would earn  $V_L^2$ . If licensing happens it would become the top firm in the H market and would earn  $V_H^1$ . Recall that  $\eta$  is the Poisson arrival rate of innovation by followers in the next instant, and  $\iota$  is the Poisson arrival rate at which the high-quality technology will be licensed to the South in the next instant.

From equations (6) and (7), we get

$$V_L^1 = V_H^1 = \frac{\pi_L^1 + \eta V_L^2}{(\rho + \eta)} \quad (8)$$

The trailing firm in the L market would be driven out by successful innovation. If licensing occurs it would become the trailing firm in the H market and earn  $V_H^2$ . Its steady-state value is thus

$$V_L^2 = \frac{\pi_L^2 + \iota V_H^2}{(\rho + \eta + \iota)} \quad (9)$$

where  $\pi_L^2$  is instantaneous profits in the absence of innovation and licensing.

Licensees in the high-quality licensing market (H) face the risk of innovation only. Recall that there is no imitation from other Southern firms. The top firm in the high-quality licensing technology market would become the trailing firm in the L market if innovation happens. Its firm value is the following:

$$V_H^1 = \frac{\pi_H^1 + \eta V_L^2}{(\rho + \eta)} \quad (10)$$

where  $\pi_H^1$  is instantaneous profit in the absence of innovation.

The trailing firm in the high-quality licensing technology market would be driven out if innovation happens. Its firm value is

$$V_H^2 = \frac{\pi_H^2}{(\rho + \eta)} \quad (11)$$

where  $\pi_H^2$  is instantaneous profit without innovation.

As discussed earlier, licensors in the H market may not be able to extract full rents from licensees because of information asymmetry and imitation risk. We model this situation as a signaling game. At the beginning of the game, the licensor has private information about the true quality level of its product. A licensor with a high-quality level wishes to convince a potential licensee of its quality type. With imperfect IPRs protection in the South the imitation cost of potential licensees is low. Thus, revealing quality type through direct inspection is not possible because the licensee may imitate the product. Instead, the high-quality licensor needs to signal its quality type through contract offers.

This game has three stages. First, the licensor offers a licensing contract, from which the licensee may be able to infer the quality type. The licensee accepts or rejects the offer. Second, if the licensee has accepted the contract, it would pay any contractually specified, up-front, fixed

fee, the technology would be transferred, and the licensee would verify the quality type by inspection. Third, the licensee decides whether or not to imitate. If the licensee imitates it would achieve full monopoly rents whereas if the licensee does not imitate it would pay any contractually specified royalties.

Consider first the low-quality licensor's rent-maximization problem. We focus on separating-equilibrium contracts following Gallini and Wright (1990). Because the licensor only faces the problem of imitation, it can extract full monopoly rents from the licensee by offering a contract charging a fixed fee equal to the licensee's monopoly rent ( $V_H^2$ ). Since the licensor extracts full rents at the beginning, the licensee has no incentive to imitate. Imitation would yield zero profit in production but would cost resources and make net profit negative.

The high-quality licensor's rent-maximizing problem is different. When designing the licensing contract, the high-quality licensor faces two challenges. On the one hand, the firm must inform the potential licensee of the quality type before the contract is signed without revealing the specifics of the technology. On the other hand, the rent-maximizing payment schedule must discourage imitation after the contract has been accepted and the technology has been transferred.

Thus, consider the separating-equilibrium contract for the high-quality licensor. Let  $F$  be the up-front fixed fee,  $\gamma$  the royalty rate, and  $C(k)$  the imitation cost by the licensee, where  $k$  is the degree of IPRs protection and  $C'(k) > 0$ . For simplicity, let  $C(k) = kC$ . The licensor's problem is as follows:

$$\begin{aligned}
 & \text{Max } (F + \gamma V_H^1) \\
 \text{S.T. } & V_H^1 - \gamma V_H^1 - F \geq 0 && \text{(rationality)} \\
 & V_H^1 - \gamma V_H^1 - F \geq V_H^1 - kC - F && \text{(no imitation)} \\
 & F + \gamma V_H^2 \leq V_H^2 && \text{(separation)}
 \end{aligned}$$

The maximum rents for the licensor that can be generated from this problem are  $V_H^i = kC + (1-\gamma)V_H^2$ , where  $\gamma = \frac{kC}{V_H^1}$ , and  $V_H^i < V_H^1$ . It follows that the maximum rents  $V_H^i$  are

$$V_H^i = V_H^2 + \theta kC, \quad (12)$$

where  $\theta = \frac{(V_H^1 - V_H^2)}{V_H^1}$ . The ratio  $\theta$  is the marginal value that the licensor would achieve if imitation cost were to increase by one unit (see Appendix B). It depends on the difference between the rents of the high-quality licensor and the low-quality licensor. In summary, the high-quality licensor must give up some rents to the licensee in order to signal its quality type. From equation (12), the licensor's rents are positively related to imitation cost  $kC$ . If IPRs protection were made tighter in the South ( $k$  were higher), the imitation cost  $kC$  would rise and the licensor would earn more rents. This system endogenizes the rent share between licensor and licensee as a function of the degree of IPRs.

Next consider the instantaneous profits earned by each kind of firm. In this model, firms use limit-pricing strategy to prevent entry of their closest competitors. In an L market the Southern licensee producing the low-quality product sets price against Southern firms residing one quality below. It sets its quality-adjusted price  $\frac{P_L^2}{\lambda^A}$  to equal the marginal cost of its competitor. We assume that each additional output unit requires one labor unit. Thus, the marginal cost of production is  $w$  in the North and we normalize the Southern wage rate at unity.

It follows that  $P_L^2 = \lambda^A$ . The trailing firm sells  $\frac{E^A}{\lambda^A}$  units of output and earns

$$\pi_L^2 = E^A \left(1 - \frac{1}{\lambda^A}\right) = E^A (1 - \delta^A) \quad (13)$$

where  $\delta^A = \frac{1}{\lambda^A}$ .

The top firm in the L market produces the high-quality product in the North. It prices against the trailing firm and sets  $P_L^1 = \lambda^B \lambda^A$ , selling  $\frac{E^B}{\lambda^A \lambda^B}$  units of output. It earns

$$\pi_L^1 = E^B \left( 1 - \frac{w}{\lambda^A \lambda^B} \right) = E^B (1 - w \delta^A \delta^B) \quad (14)$$

where  $\delta^B = \frac{1}{\lambda^B}$ .

In the H market the trailing firm is a Southern licensee producing the low-quality product. It prices against Southern firms residing one quality below, sets  $P_H^2 = \lambda^A$ , and earns

$$\pi_H^2 = E^A \left( 1 - \frac{1}{\lambda^A} \right) = E^A (1 - \delta^A) \quad (15)$$

The top firm in the H market is a Southern licensee producing the high-quality product. It prices against the trailing firm, sets  $P_H^1 = \lambda^B \lambda^A$ , and earns

$$\pi_H^1 = E^B \left( 1 - \frac{1}{\lambda^A \lambda^B} \right) = E^B (1 - \delta^A \delta^B) \quad (16)$$

Note that  $\pi_L^2 = \pi_H^2$ , because low-quality products are produced in the South with the same marginal costs. From this, it is easy to show that

$$V_L^2 = V_H^2 = \frac{\pi_H^2}{(\rho + \eta)} = \frac{\pi_L^2}{(\rho + \eta)} \quad (17)$$

These limit-pricing outcomes are supported by a Nash-equilibrium pair of firm strategies in a repeated game with an infinite number of repetitions. The firm wants to maximize its expected value instead of its instantaneous profits in an infinite horizon. If it were a one-shot game, with more than one quality level of a product sold in equilibrium, the limit price chosen by

the top firm in a separating equilibrium would allow the trailing firm to lower its own price by a small amount and capture the entire market. But in a repeated game if the trailing firm were to undercut the top firm's price in the first period, the top firm could punish it in all following periods and make its profits zero forever. Therefore, as long as the discount rate is not too high, the above limit-price outcomes will be an equilibrium. The top firm can limit-price against the trailing firm even if the trailing firm prices above cost.

### **Resource Market Clearance**

In equilibrium, all resources are fully used for production and innovation in both the North and South. We only have one input, labor. Let the labor supply in the North be  $D_N$  and the labor supply in the South be  $D_S$ , where both are exogenously given. We denote the measure of the high-quality licensing market as  $n_H$  and the measure of the low-quality licensing market as  $n_L$ . The Northern labor-market clearance condition is

$$a\eta(n_H + n_L) + n_L E^B \delta^A \delta^B = D_N \quad (18)$$

The first term represents labor resources used in innovation and the second term represents labor used in producing high-quality goods. The Southern labor-market clearance condition is given by

$$E^A \delta^A + n_H E^B \delta^A \delta^B = D_S \quad (19)$$

The first term is labor used in producing low-quality products and the second term is labor used in the production of high-quality products.

### **Constant Steady-State Market Shares**

In a steady-state equilibrium, measures of products produced in the L and H markets are constant. Recall that  $n_L$  denotes the proportion of industries with high-quality products produced in the North and low-quality products produced in the South, while  $n_H$  denotes the proportion of industries with both high-quality and low-quality products licensed to the South. Thus, the flow

of production out of the L market must be the same as that into the H market, and the flow of production out of the H market must be the same as that into the H market, as indicated in equation (20):

$$\iota n_L = \eta n_H \quad (20)$$

The flow out of the L market is  $\eta n_L dt + \iota n_L dt$  for an interval  $dt$ . The flow into the L market is  $\eta n_L dt + \eta n_H dt$  for an interval  $dt$ . Further,

$$n_L + n_H = 1 \quad (21)$$

### 3. Steady-State Equilibrium and the Effects of IPRs

#### 3.1 Steady-State Equilibrium

Define  $\phi$  as the aggregate rate of licensing high-quality technology:  $\phi = \iota n_L$ . From equations (20) and (21),  $n_H = \frac{\phi}{\eta} = n$ , which we term the extent of high-quality licensing. The task is to solve for four endogenous variables ( $\eta$ ,  $n$ ,  $E$ , and  $w$ ) in terms of the exogenous variables.

The resource constraints (18) and (19) may be solved for aggregate expenditure  $E$ :

$$E = \frac{D_N + D_S - a\eta}{(1 - f^B)\delta^A + f^B \delta^A \delta^B} \quad (22)$$

Recall that  $f^B$  is the share of income accruing to the high-valuation consumers. Eliminating  $E$  from equation (18) using equation (22), a joint resource constraint in terms of endogenous variables  $\eta$  and  $n$  is derived:

$$a\eta + (1 - n)(D_N + D_S - a\eta)\mu = D_N \quad (23)$$

where  $\mu = \frac{f^B \delta^A \delta^B}{(1-f^B)\delta^A + f^B \delta^A \delta^B}$ . Equation (23) gives the relationship between innovation  $\eta$

and high-quality licensing  $n$  when resource constraints in both the North and the South are

satisfied. Taking total derivatives of this equation shows that  $\frac{d\eta}{dn} > 0$  and  $\frac{d^2\eta}{dn^2} < 0$ . Therefore,

as  $n$  increases  $\eta$  rises also but at a decreasing rate. The intuition behind this positive relationship is straightforward. When licensing goes up more production is transferred to the South, making more resources in the North available for innovation.

Substituting equations (8), (9), (11), (12), (13), (14), (15), and (17) into equations (5) and (6) yields the following valuation equations:

$$(wa - \theta kC)(\rho + \eta) = E(1 - f^B)(1 - \delta^A) \quad (24)$$

$$\rho wa = Ef^B(1 - w\delta^A\delta^B) - \eta\theta kC \quad (25)$$

Eliminating  $w$  from equations (24) and (25), we get a joint valuation equation:

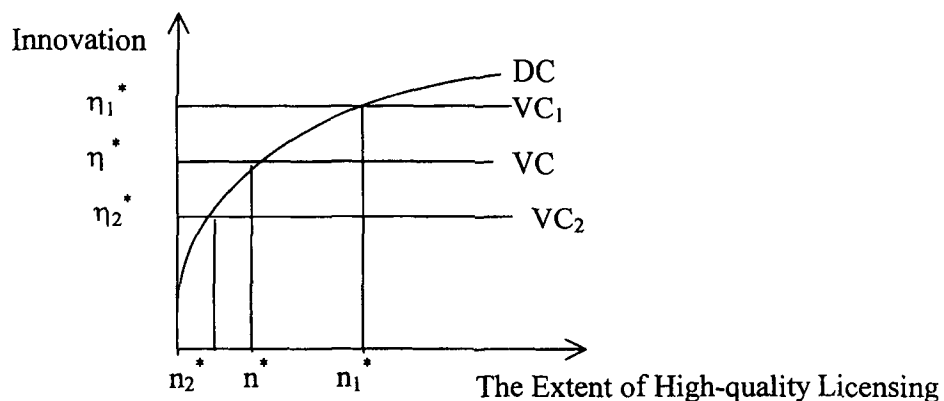
$$a(\rho + \eta)(Ef^B - \eta\theta kC) = [E(1 - f^B)(1 - \delta^A) + (\rho + \eta)\theta kC](a\rho + Ef^B\delta^A\delta^B) \quad (26)$$

Note that  $n$  has no effect on this joint valuation equation, since  $E$  depends on  $\eta$  only in equation (22).

We depict the combinations of  $\eta$  and  $n$  that satisfy the joint resource constraint (equation (23)) as the curve labeled DC in Figure 2. It is positively sloped and concave. The curve labeled VC in Figure 2 shows the combinations of  $\eta$  and  $n$  that satisfy the joint valuation equation (26). The intersection between DC and VC gives the steady-state equilibrium rates of innovation and licensing.



**Figure 2: Steady-State Innovation and Licensing**



### 3.2 Comparative Statics

#### Innovation and Technology Transfer

We now study the effects of tighter IPRs protection in the South. The impacts on equilibrium rates of innovation and technology transfer may be derived using the joint resource constraint (23) and the joint valuation equation (26). The protection of IPRs is built into the model through imitation cost of the licensee. If IPRs were strengthened  $kC$  would increase. Note that  $k$  appears only in the joint valuation equation (26) and has no effect on the joint resource constraint. However, by affecting innovation, IPRs alter technology transfer through the resource constraints.

To determine the effect of IPRs on innovation through the joint valuation equation, substitute  $E$  from equation (22) into equation (26) and take total derivatives to achieve an expression for  $\frac{d\eta}{dk}$ . Equivalently, totally differentiate equations (24) and (25) to arrive at a system of equations for  $\frac{d\eta}{dk}$  and  $\frac{dw}{dk}$ . Appendix D solves this equation system and shows that the sign of  $\frac{d\eta}{dk}$  could be positive or negative. Therefore, in response to stronger IPRs in the South, the VC curve in Figure 2 could shift up or shift down and the effects of IPRs on innovation and the extent of licensing are ambiguous.

We resolve this ambiguity in Appendix D by deriving a sufficient condition for  $\frac{d\eta}{dk}$  to be positive.<sup>4</sup> This condition holds if the ratio of labor used in innovation to labor used in production of goods of both quality levels in the world is lower than a critical value  $P^*$ , where  $P^*$  is less than unity and depends on parameter values of  $\delta^A$ ,  $\delta^B$ , and  $f^B$ . In this case, the VC curve would shift up to  $VC_1$  in Figure 2. Thus, with stronger IPRs protection in the South, both innovation ( $\eta^*$ ) and licensing ( $n^*$ ) would increase. We summarize our results in Proposition I.

*Proposition I*

*If the size of the labor force used in innovation relative to that used in the production of goods in the world is sufficiently small, stronger IPRs in the South would lead to both a higher rate of innovation and a higher extent of licensing high-quality technology.*

The intuition behind Proposition I is as follows. In choosing whether to license a successfully innovated technology to the South, Northern firms must find a balance between lower labor cost in the South and the rents given up through licensing. If tighter IPRs protection were adopted in the South, the rents that the licensor must sacrifice to prevent imitation from the licensee would decrease. Thus, the rents from licensing would rise and so would the return from innovation. However, if the resulting increase in labor demand in innovation were high, considerable resources would be drawn away from Northern production. In turn, this would markedly raise demand for Southern labor to produce both high-quality and low-quality goods, causing the Southern relative wage to increase and the Southern labor cost advantage to decrease. Only when the labor force used in innovation relative to that used in production is small would innovation in the North not force up the Southern wage enough to overturn its labor-cost advantage. In this case, an increase in licensing rents with stronger IPRs protection would give Northern innovative firms a larger incentive to innovate and these firms would transfer more high-quality production to the South through additional licensing.

### **Relative Wage Between the North and South**

Appendix D shows that the derivatives  $\frac{dw}{dk}$  and  $\frac{d\eta}{dk}$  have opposite signs. Therefore we have Proposition II.

*Proposition II*

*If stronger IPRs in the South cause innovation and technology transfer to increase, the relative Southern wage ( $\frac{1}{w}$ ) would rise. However, if stronger IPRs cause innovation and technology transfer to decrease, the relative Southern wage would fall.*

The intuition behind Proposition II is as follows. On the one hand, when innovation rises the demand for Northern labor goes up and the Northern relative wage increases (the Southern relative wage decreases). On the other hand, when there is more technology transfer to the South ( $n$  increases), the demand for Southern labor goes up and therefore the Southern relative wage rises. Recall that the sufficient condition for innovation to rise is that innovation demands a small share of labor resources. Thus, when this condition holds the latter effect would dominate and the Southern relative wage would rise with more innovation and licensing.

**4. Conclusions**

Licensing as a channel of technology transfer from the North to South has been ignored in the literature. We develop a model of licensing contracts in imperfect markets to study the effects of IPRs on innovation and technology transfer in a dynamic general-equilibrium, product-cycle model with multiple product qualities. The novel features here are the incorporation of asymmetric information and imitation risk in licensing into a general-equilibrium framework and the endogenization of the rent share between the licensor and the licensee as a function of the degree of IPRs in the South.

Results from the model show that stronger IPRs in the South would increase the rate of innovation and the extent of high-quality licensing from the North to the South under a particular condition. Specifically, this outcome requires that the labor force used in innovation, compared to that used in the production of goods anywhere in the world, is sufficiently small and that there remains a relatively large advantage of lower labor cost in the South. This condition seems consistent with reality, for the innovation sectors in even the developed countries (measured by the share of R&D) rarely exceeds three percent of GDP while production activity in the world is far larger. These results are different from prior major findings in the literature, in which stronger IPRs in the South would reduce the rates of innovation and technology transfer when imitation and FDI are channels of technology transfer. Our results are more optimistic about the impacts of stronger IPRs as mandated by the TRIPs agreements under the WTO.

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## Appendix A. Condition for Separation

In the L market, if a top firm chooses pooling, it would charge  $P^P = \lambda^A$  (where the superscript  $P$  indicates pooling) because it wants to capture the whole market. It sells  $\frac{E}{\lambda^A}$  units of products and earns instantaneous profits  $\pi^P = E(1 - \frac{w}{\lambda^A}) = E(1 - w\delta^A)$ . The top firm's expected value is  $V^P = \frac{\pi^P}{\rho + \eta}$ .

If the top firm chooses separation (here labeled with superscript  $S$ ), it would charge  $P^S = \lambda^A \lambda^B$ . It sells  $\frac{E^B}{\lambda^A \lambda^B}$  units of products, and earn instantaneous profits  $\pi^S = E f^B (1 - \delta^A \delta^B w)$ . Its expected firm value is  $V^S = \frac{\pi^S + \eta V_L^2}{\rho + \eta}$ .

Separation occurs in the L market iff  $V^S > V^P$ . Thus  $\pi^S > \pi^P$  is a sufficient condition that separation will happen. The condition  $\pi^S > \pi^P$  is satisfied if  $f^B > \frac{1 - \delta^A w}{1 - \delta^A \delta^B w}$ .

Similarly, in the H market, under pooling the top firm would charge  $P^P = \lambda^A$  and get instantaneous profits  $\pi^P = E(1 - \frac{1}{\lambda^A}) = E(1 - \delta^A)$ . The firm has expected value

$V^P = \frac{\pi^P}{\rho + \eta}$ . Under separation, it would charge  $P^S = \lambda^A \lambda^B$  and get instantaneous profits

$\pi^S = E f^B (1 - \delta^A \delta^B)$ . Its expected firm value is  $V^S = \frac{\pi^S + \eta V_L^2}{\rho + \eta}$ . Separation is assured by

$\pi^S > \pi^P$ , therefore, separation occurs if  $f^B > \frac{1 - \delta^A}{1 - \delta^A \delta^B}$ .

If separation occurs in the H market, it will also occur in the L market, because if

$f^B > \frac{1 - \delta^A}{1 - \delta^A \delta^B}$ , then  $f^B > \frac{1 - \delta^A w}{1 - \delta^A \delta^B w}$  holds automatically. Therefore, separation occurs in

both the H and L markets if  $f^B$  is greater than  $\frac{1 - \delta^A}{1 - \delta^A \delta^B}$ . In other words, separation occurs if

high-valuation consumers have a sufficiently high income share.



## Appendix B. Rent Maximization for the High-Quality Licensor

First, we show that  $V_H^1 > V_H^2$  in this model. From equations (10) and (11) we see that

$$V_H^1 - V_H^2 = \frac{E[(\rho + \eta)f^B(1 - \delta^A\delta^B) - \rho(1 - f^B)(1 - \delta^A)]}{(\rho + \eta)^2} \quad (\text{B1})$$

From the condition  $f^B > \frac{1 - \delta^A}{1 - \delta^A\delta^B}$  in Appendix A, it follows immediately that

$$V_H^1 - V_H^2 > 0.$$

Next we solve the rent-maximizing problem for the high-quality licensor. The Lagrangian function for the high-quality licensor's problem is as follows:

$$L = F + \gamma V_H^1 + \varepsilon (V_H^1 - \gamma V_H^1 - F) + \nu (kC - \gamma V_H^1) + \beta (V_H^2 - F - \gamma V_H^2)$$

The Kuhn-Tucker conditions are:

$$\partial L / \partial F = 1 - \varepsilon - \beta \leq 0 \quad \perp \quad F \geq 0 \quad (1k)$$

$$\partial L / \partial \gamma = V_H^1 - \varepsilon V_H^1 - \nu V_H^1 - \beta V_H^2 \leq 0 \quad \perp \quad \gamma \geq 0 \quad (2k)$$

$$\partial L / \partial \varepsilon = V_H^1 - F - \gamma V_H^1 \geq 0 \quad \perp \quad \varepsilon \geq 0 \quad (3k)$$

$$\partial L / \partial \nu = kC - \gamma V_H^1 \geq 0 \quad \perp \quad \nu \geq 0 \quad (4k)$$

$$\partial L / \partial \beta = V_H^2 - F - \gamma V_H^2 \geq 0 \quad \perp \quad \beta \geq 0 \quad (5k)$$

where  $\perp$  denotes the complementary-slackness condition (if  $A \geq 0$  and  $B \geq 0$  then  $AB = 0$ ).

Three exhaustive cases are considered:

Case I:  $F > 0$  and  $\gamma = 0$ ; Case II:  $F = 0$  and  $\gamma > 0$ ; Case III:  $F > 0$  and  $\gamma > 0$ .

It is easy to show there are no solutions for Case I and Case II given that  $V_H^1 > V_H^2$  and  $kC > 0$ .

Only Case III is left. There are eight different sub-cases for Case III:

- |   |   |
|---|---|
| (a) $\varepsilon = 0, \nu = 0, \beta = 0$ ; | (e) $\varepsilon = 0, \nu = 0, \beta > 0$ ; |
| (b) $\varepsilon > 0, \nu = 0, \beta = 0$ ; | (f) $\varepsilon > 0, \nu = 0, \beta > 0$ ; |
| (c) $\varepsilon = 0, \nu > 0, \beta = 0$ ; | (g) $\varepsilon = 0, \nu > 0, \beta > 0$ ; |
| (d) $\varepsilon > 0, \nu > 0, \beta = 0$ ; | (h) $\varepsilon > 0, \nu > 0, \beta > 0$ ; |

Sub-cases (a) to (f) and sub-case (h) can be ruled out easily because of conflicts among different conditions. Thus, only sub-case (g) is left. The solution for sub-case (g) is as follows:

$$\varepsilon + \beta = 1 \text{ and } \beta = 1, \varepsilon = 0 \quad (6k) \quad (\text{from (1k) and (g)})$$

$$(1 - \nu) V_H^1 = V_H^2 \quad \text{and} \quad \nu = \frac{V_H^1 - V_H^2}{V_H^1} \quad (7k) \quad (\text{from (2k) and (6k)})$$

$$F + \gamma V_H^1 \leq V_H^1 \quad (8k) \quad (\text{from (3k) and } \varepsilon = 0)$$

$$\gamma V_H^1 = kC \quad (9k) \quad (\text{from (4k) and } \nu > 0)$$

$$F + \gamma V_H^2 = V_H^2 \quad (10k) \quad (\text{from (5k) and } \beta > 0)$$

From equations (9k) and (10k) we get  $F + \gamma V_H^1 = kC + (1-\gamma) V_H^2 = V_H^2 + \theta kC$  and

$\gamma = \frac{kC}{V_H^1}$  (here we have substituted  $\theta$  for  $\nu$ , with  $\theta$  being the ratio used in the text). In Appendix C

we show that  $V_H^1 > V_H^2 + \theta kC$  in this model. Therefore, the maximum rents for the licensor are  $V_H^2 + \theta kC$ . In summary, to have an optimal solution for this problem, both  $F$  and  $\gamma$  must be positive, both the non-imitation and the separation constraints are binding, and the rationality constraint is not binding. As a result, the licensor has to share some rents with the licensee. Because the objective function is concave and the constraints are convex, the Kuhn-Tucker conditions are necessary and sufficient.

#### Appendix C. The Condition $\theta kC < V_H^1 - V_H^2$

From the equilibrium licensing condition [equation (6)], we have

$$E f^B (1 - \delta^A \delta^B w) - \frac{\rho}{\rho + \eta} E (1 - f^B) (1 - \delta^A) = (\rho + \eta) \theta kC \quad (C1)$$

From equations (C1), (B1), and the assumption  $w > 1$ , we have

$$\theta kC < \frac{E[(\rho + \eta) f^B (1 - \delta^A \delta^B) - \rho (1 - f^B) (1 - \delta^A)]}{(\rho + \eta)^2} = V_H^1 - V_H^2$$

#### Appendix D. The sign of $\frac{d\eta}{d(kC)}$ and $\frac{dw}{d(kC)}$

Total differentiation of equations (24) and (25) give a system of equations:

$$\begin{bmatrix} a(\rho + \eta) & [(wa - \theta kC) - (\rho + \eta)(kC) \frac{d\theta}{d\eta} - (1 - f^B)(1 - \delta^B) \frac{dE}{d\eta}] \\ (\rho a + Ef^B \delta^A \delta^B) & [\theta kC + \eta kC \frac{d\theta}{d\eta} - f^B(1 - w\delta^A \delta^B) \frac{dE}{d\eta}] \end{bmatrix} \begin{bmatrix} \frac{dw}{dkC} \\ \frac{d\eta}{dkC} \end{bmatrix} = \begin{bmatrix} (\rho + \eta)\theta \\ -\eta\theta \end{bmatrix}$$

Let A to be the first matrix of the left-hand side, and B to be the matrix of the right hand side, then

$$\begin{bmatrix} \frac{dw}{dkC} \\ \frac{d\eta}{dkC} \end{bmatrix} = \frac{1}{|A|} \begin{bmatrix} H_1 \\ H_2 \end{bmatrix}$$

where

$$H_1 = \rho\theta[\theta kC - f^B(1 - w\delta^A \delta^B) \frac{dE}{d\eta}] + \eta\theta\{wa - \frac{dE}{d\eta}[(1 - f^B)(1 - \delta^B) + f^B(1 - w\delta^A \delta^B)]\} > 0,$$

since  $\frac{dE}{d\eta} < 0$ , and  $H_2 = -\theta(\rho + \eta)[\rho a + Ef^B \delta^A \delta^B] - \eta\theta a(\rho + \eta) < 0$ .

Therefore, no matter what the sign of  $|A|$  is,  $\frac{d\eta}{d(kC)}$  and  $\frac{dw}{d(kC)}$  have opposite signs.

The sign of the determinant  $|A|$  and the sign of  $H_2$  decide the sign of  $\frac{d\eta}{dk}$ . For analytical

simplicity,  $|A|$  is derived for the case  $\rho = 0$ . It can be shown that if  $\frac{a\eta}{(D_N - a\eta) + D_S} < P^*$ , then

$|A| < 0$  and therefore  $\frac{d\eta}{dk} > 0$ , where  $P^* = \frac{(1 - \delta^A)(1 - f^B)\delta^A \delta^B}{(1 - \delta^A \delta^B)[(1 - f^B)\delta^A + f^B \delta^A \delta^B]}$ . It is easy to show

that  $P^* < 1$ . Recall  $a\eta$  is the labor used in innovation, and  $(D_N - a\eta) + D_S$  is the labor used in the production of high-quality and low-quality goods.

## ENDNOTES

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<sup>1</sup> Ethier (1986) first incorporated informational asymmetry in licensing into a general equilibrium framework. However, he focused on conditions to achieve incentive-compatible arm's-length contract and the choice between FDI and licensing. We solve for a specified incentive-compatible licensing contract when there are both informational asymmetry and imitation risk.

<sup>2</sup> Licensing also costs resources in transferring the “know-how” (see Teece, 1976). Here transaction costs in licensing are set to zero for simplicity.

<sup>3</sup> Determination of these profit flows is taken up later in this section.

<sup>4</sup> For analytical simplicity, the results for case of  $\rho = 0$  are derived. For cases where  $\rho \neq 0$  numerical results will be provided upon request.





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