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International Joint Ventures under Imperfect Protection of Intellectual Property Rights and Aysmmetric Information

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Abstract: In this paper, I develop a quality ladder product cycle model with two quality levels to examine the effects of intellectual property rights (IPRs) protection on the extent of international joint ventures (JVs) and the rate of innovation under asymmetric information and imitation risk. The Northern share of a JV is endogenously determined. An optimal Northern share of a JV is an increasing function of Southern IPRs. With asymmetric information problem and imitation risk, an optimal JV contract involves giving a Southern partner a larger share of a JV when Southern IPRs are weaker, and giving a smaller share when Southern IPRs are stronger. The results are that stronger Southern IPRs increase the extent of JVs, the rate of innovation and the relative wage. In the case of low-quality technology transfer, licensing is a preferred mode of technology transfer. In the case of high-technology transfer, a JV is a preferred mode of technology if the cost of imitation under a JV contract is sufficiently higher than the cost of imitation under licensing contracts.

JEL classification: F12, F23, O34, D82
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Introduction

As a result from the Uruguay Round of Multinational Trade Negotiation, the agreement on Trade-Related Aspects of Intellectual property right (TRIPs) requires all WTO members to adopt minimum standard set by WTO within designated time. An important argument relating IPRs is whether stronger intellectual property rights in developing countries encourage international technology transfer and innovation. International technology transfers through three important channels that are foreign direct investment, licensing and joint venture. There exists a large numbers of literatures regarding the relationship between IPRs and technology transfer such as FDI and licensing. However, what is missing from the literature is an examination of the relationship between intellectual property rights, joint ventures (JVs) and innovation, particularly in a dynamic setting. Although, American joint venture activity is declining continuously since 1980s, international joint venture is an important mode of technology transfer in some countries and deserves some analytical studies. In addition, economic growth of developing countries such as India and China where the local government prohibits 100% foreign-ownership (FDI) relies on technology transfer from JVs. In the paper, I use a product-cycle dynamic general equilibrium model to study the effects of intellectual property right on joint venture and innovation. In addition, the model incorporates asymmetric information in technology transfer from the North to the South.

The main difference among channels of technology transfer stated above is the ownership of the producing firm. In the case of FDI, a multinational firm has a 100% ownership over a producing firm in the South. In the case of licensing, a licensor (the North) sells technology to a licensee (the South) and has no ownership over the producing firm. In the case of joint venture, a Northern firm and a Southern firm share an ownership over a joint venture firm. A joint venture (JV) in this paper is defined as an entity that has been operated and jointly controlled by two partners. In addition, both partners share the profit of a joint venture firm. The Northern partner that has superior ability to conduct R&D transfers technology to the JV, and a JV hires a cheap labor to produce a product in the South. There are two quality levels of technology, high and low. The low-quality product is immediately transferred to the South in the form of joint venture. The Northern multinational enterprises (MNEs) that have an access to the more advanced technology transfer their hi-tech technology to the South in form of joint venture if they are indifference between transferring technology and production to the South and continuing the production in the North. When a Northern MNE forms a joint venture, MNE and the Southern partner share expected market vale of a JV. As in Gallini and Wright (1990), the Northern partner faces asymmetric information and imitation risk in transferring technology to JV. Under asymmetric information with two levels of technology, the high quality northern partner needs to differentiate it from a low quality northern partner. Under imitation risk, the northern partner is reluctant to transfer technology to JV without a commitment by the southern partner not to imitate. Thus, northern partner have a task to design a contract that not only signal its true quality level but also discouraging imitation.

Since technology transfer occurs through multiple channels. Northern multinationals can choose the mode of technology transfer based on the payoff from transferring their technology. An interesting question is “what is the preferred mode channel of technology transfer under asymmetric information and imitation risk?”. This paper compares optimal JV contact and licensing contracts. Two types of licensing contracts are studied in the paper; a contract with an upfront fixed fee and output based royalties and a contract with an upfront fixed fee and proportional royalties. We derive the condition under which a JV contract is more preferred to licensing contracts.

The structure of the paper is the following: The second section is the literature review. The third section is the model. The fourth section is solutions in the steady-state equilibrium and analyses on IPRs and JV. The fifth section is the comparison between licensing contracts and a JV contract. The last section provides conclusions.

Literature Review

Intellectual property right protection is a widely debated issue. Mostly, existing papers related to IPRs try to answer the question "How does IPRs affect technology transfer and innovation?". Technology transfer is crucial to the economic growth of developing countries. In addition, globalization and advanced technology allow technology to transfer easier and faster. Generally, stronger IPRs help the developing countries to attract technology transfer from the developed countries and encourage innovation. There are many channels of technology transfer such as imitation, foreign direct investment, licensing and joint venture. However, TRIPs agreement discourages imitation and thus, WTO members have to rely more on alternative channels. Examples of papers concerning the effect of IPRs on technology transfer and innovation are Lai (1998), Glass and Saggi (2002), Glass and Wu (2003), and Yang and Maskus (2001 and 2002).

Lai (1998) uses a model where innovation is associated with new varieties, and a stronger IPR is an exogenous decrease in the imitation intensity to study the effect of IPRs on FDI and the rate of innovation. He finds that if FDI is the only channel of technology transfer, stronger IPRs increase the rate of innovation and FDI. In contrast, Glass and Saggi (2002) use a model where innovation is associated with a higher quality of product to study the effect of IPRs on FDI, imitation and innovation. A stronger IPR is modeled as an increase in the cost of imitation They find that stronger IPRs reduce FDI and innovation. Their intuition is that stronger IPRs require more resource used in imitation resulting in fewer resources left for FDI. Less FDI implies that more productions remain in the North resulting in fewer resources left for innovation. Glass and Wu (2003) use a model where innovation is associated with a higher quality of product, and a stronger IPR is an exogenous decrease in the imitation intensity to study the effect of IPRs on FDI and innovation. They find that a stronger IPR discourages FDI and innovation. Thus, whether IPRs increase FDI is sensitive on the type of innovation. If innovation is an improvement in quality, stronger IPRs discourage the FDI and innovation. However, if innovation is an increase in variety, stronger IPRs encourage FDI and innovation.

Yang and Maskus (2001) use a product cycle model where a weak IPR is associated with the higher licensor's rent share to study the effect of IPRs on innovation and the extent of licensing. They find that stronger IPRs encourage licensing and innovation. The intuition is the follow. Stronger IPRs reduce licensing cost and raise the rent share of the licensor and therefore encourage licensing and innovation. Yang and Maskus (2002) use a product cycle model with two-quality level of each product in equilibrium to study the effect of IPRs on innovation and licensing. In addition, in their model, the licensor faces both asymmetric information problem and imitation risk. The licensor's rent is determined endogenously as a function of level of IPR. They find that a stronger IPR encourages innovation and licensing if the labor used innovation compared to that used in the production is sufficiently small and that there remains a relatively large advantage of lower labor cost in the South.

From reviewed papers on IPRs and licensing, we conclude that strong IPRs help developing countries to attract technology transfer through licensing if there is no asymmetric information problem. However, under asymmetric information problem, stronger IPRs encourage innovation and licensing under some conditions. Although the effect of IPRs on technology transfer such as FDI and licensing has been studied quite extensively, the effect IPRs on joint venture remains unexplored and therefore deserves a careful study.

In term of modeling the contractual design, this paper is closely related to Gallini and Wright (1990) and Yang and Maskus (2002). However, this paper focuses on the optimal share of expected market value of a JV between the North and the South, which is the key of a joint venture agreement. The joint venture optimal contract involves giving up some ownership advantage to solve the problem of imitation and asymmetric information. In Gallini and Wright (1990), the licensing contract consists of an upfront fixed fee and output based royalties. In this paper, we call a contract specified in Gallini and Wright (1990) a LO contract. An optimal LO contract involves leaving some monopoly rent to the licensee in order to solve asymmetric information and imitation problems. In Yang and Maskus (2002), the licensor designs an optimal contract consisting of an upfront fixed fee and proportional royalties, which is a proportion of the monopoly rent, to signal the true quality of technology transferred and discourage licensees from imitating their product. In this paper, we name contract specified in Yang and Maskus (2002) a LP contract. Similar to Gallini and Wright (1990), the licensor's optimal licensing contract involves giving up some monopoly rent to solve the problem of imitation and asymmetric information. Comparing a Northern share a JV to Licensors' rents allow us to build a condition under which JV is a more preferred mode of technology transfer.

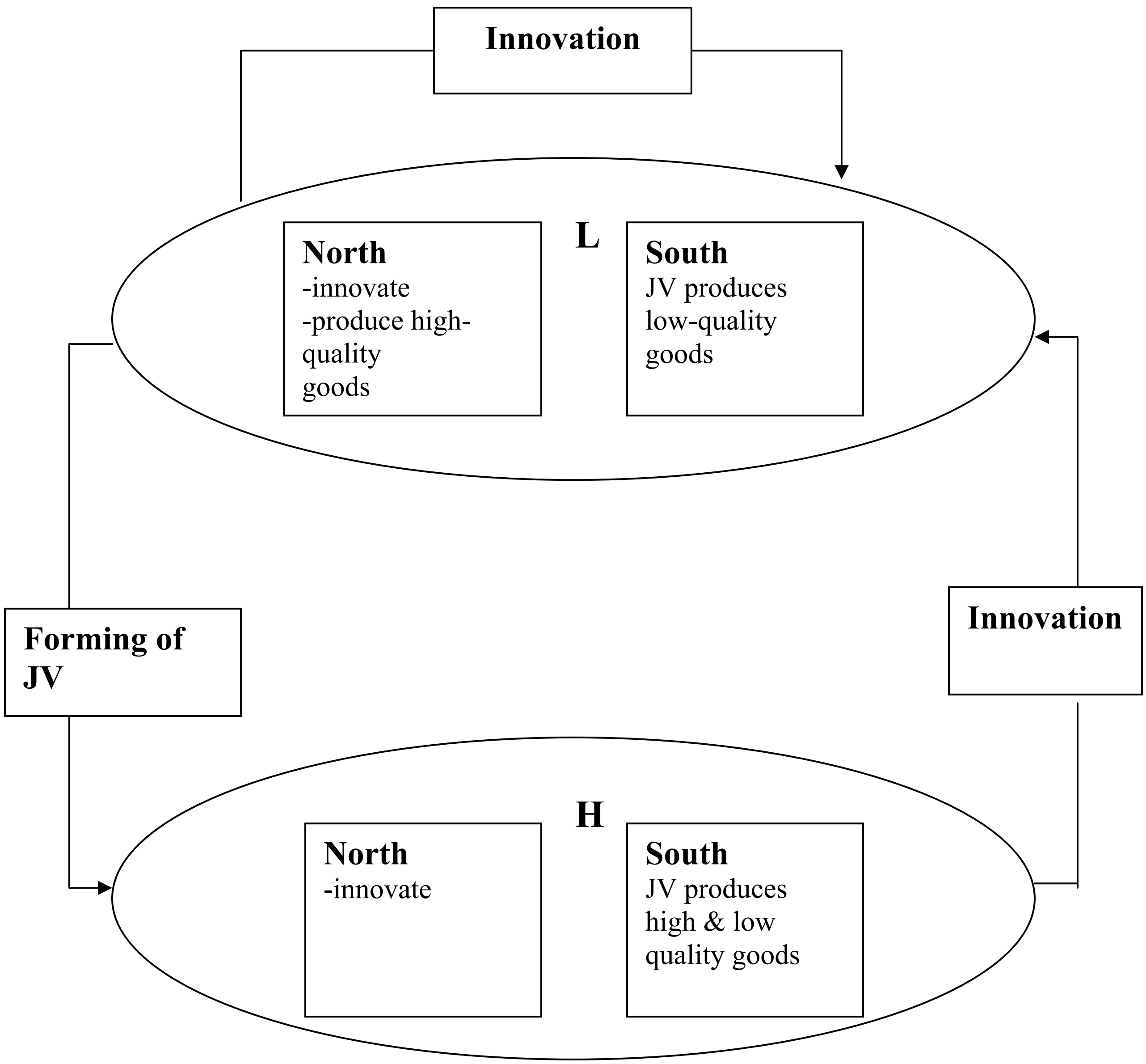
Market Structure

In this paper, I focus on the Southern country that a local government does not allow 100% foreign-ownership. Thus, a multinational firm is not able to transfer technology and production in form of FDI but able to transfer technology and production to a JV firm in the South. I further assume that in the absence of JVs, Southern partner does not have the technology to produce both quality levels of goods. In other words, Southern firms only have an access to technology that no longer yield profit from the production. Productions of either or both Northern goods (high and low-quality) could be produced in the South by JV firms located in the South only. Further assume that the direct imitation from imported goods is extremely expensive and is prohibited in the model. Thus, JV is the only channel of technology transfer from the North to the South. However, once JV is formed, Southern partner could imitate Northern partner's product at some cost at which is positively correlated with the level of Southern IPRs. This means the stronger Southern IPRs is, the higher the cost of imitation. Moreover, Southern firms rather than the Southern partner of a JV cannot imitate a JV's product due to the limit pricing and less imitating ability. A JV would set the price just equal to the imitator's marginal cost and prevent an imitating firm having positive profits.

There are two qualities of product sold in equilibrium at any point in time. The production of high-quality product requires one-quality high level of technology above the production of low-quality product. Following Yang and Maskus (2002), firm that had innovated the current state-of-the-art technology is the leader, and other firms that had invented a one-quality level below the state-of-the-art is the follower. As in Grossman and Helpman (1991), I assume that the leader will not conduct R&D to improve the quality of its own product. All improvements on the current state-of-the-art product are done by followers.

Similar toYang and Maskus (2002), there are two markets (low-quality JV and high-quality JV) co-existing in the equilibrium. In the low-quality JV market (L), a Northern follower forms a JV with a Southern partner and transfer technology required in the production of low-quality product to a JV, while the production of high-quality product remains in the North. Whenever, followers invent a new highest-quality product, the leader becomes the followers and the technology and production of the new low-quality is transferred to the South in form of a JV. Once there is a successful innovation, the production of previous high-quality product is automatically transferred to the South in the form of a JV. In the high-quality JV market, a Northern leader may form a JV with a Southern partner and transfer technology required in the production of high-quality product to a JV. Thus, the production of both high-quality and low-quality are produced by JVs (one JV produces one product) in the South. The H market becomes L market whenever there is a successful innovation targeting the current high-quality in H market.

The market structure is presented in Figure 1.



Picture 1. Market Structure

Consumers

The consumption side is similar to Glass and Saggi (1998) and Yang and Maskus (2002). There are two types of consumer, $\omega \in [A, B]$ where A is low-type), and B is high-type. Consumers choose from a continuum of products indexed by $j \in [0,1]$ that can be improved an infinite number of times, indexed by m =0,1,2,3…... The increment to quality is λ^m. The high-type consumers (B) value quality improvement more than low-type consumers (A) that is $\lambda^B > \lambda^A > 1$. Consumers of each type ω in each country i maximize lifetime utility subject to an intertemporal budget constraint. The intertemporal utility function for the representative consumer of type ω in country i is

$$U_i^\omega = \int_0^\infty e^{-\rho t} \log u_i^\omega(t) dt \tag{1}$$

,where ρ is the common subjective discount rate. Instantaneous utility is

$$\log u_i^\omega(t) = \int_0^1 \log\left[\sum_m (\lambda^\omega)^m x_{im}^\omega(j,t)\right] dj \tag{2}$$

$(\lambda^\omega)^m$ is the assessment by type ω consumers of quality level m ,and $x_m^\omega(j,t)$ is consumption by type ω of quality level m of product j at time t.

The intertemporal budget constraint is

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

,where $R(t) = \int_0^t r(s) ds$ is the cumulative interest rate up to time t, and $A^\omega(0)$ is the value of initial asset holdings plus labor income of type ω consumers. The aggregate spending of type ω consumer is

$$E^{w}(t) = \int_{0}^{1} \left[\sum_{m} p_{m}(j,t) x_{m}^{w}(j,t) \right] dj \tag{4}$$

,where $p_m(j,t)$ is the price of quality level m of product j at time t. The aggregate spending is $E = E^A + E^B$. f^A is a share of world income that belongs to type A consumer, and $f^B = 1 - f^A$ is a share of world income that belongs to type B consumer. Therefore, $E^A = Ef^A$ and $E^B = Ef^B$.

The consumer problem can be broken into three states. In the first stage, consumers evenly spread lifetime spending for each product across time. Since aggregate spending is constant across tome, the interest rate at each point in time reflects the subjective discount rate, $r(t) = \rho$. In the second stage, consumers evenly spread spending across product at any time. In the last state, consumers evenly allocate spending for each product at any time to the quality level that has the lowest quality adjusted price.

Innovation and Joint Venturing

Assume that innovation activity must precede only one quality level at a time. A successful innovation is modeled as a continuous Poison process. A Northern firm undertaking innovation intensity η for a time interval dt requires $a\eta dt$ units of labor at cost $wa\eta dt$ and leads to success with probability ηdt. The Northern wage is w^N. The Southern wage, w^S, is normalized to 1. $w = \frac{w^N}{w^S}$ is the Northern relative wage. a is labor requirement in the innovation activity. A successful innovator earns market value of V_L^1 in L market. The free entry condition in the Northern R&D market is that the expected profits must not exceed costs.

Free entry condition is

$$V_L^1 \le wa, \eta > 0 \Leftrightarrow V_L^1 = wa \tag{5}$$

. After a Northern firm is successful in inventing the new state-of-the-art product, it chooses to produce domestically or transfer the production to the South in the form of a JV. The joint venturing decision is also a random process. Assume that the duration between the time of innovation and the time of joint venturing has an exponential distribution with a density $\Pr(\tau \le t) = 1 - e^{jt}$, where j is the Poisson arrival rate at which the high-quality technology will be transfer to the South in the form of a JV. The joint venture process requires Southern resources used in adaptation[1] Northern technology (b) to the Southern environment. The adaptation cost[2] includes the cost such as of the learning cost of Southern labor to use the new technology and the cost of adapting the machines to use in Southern environment. A Northern firm undertakes joint venture intensity j for a time interval dt requires $bjdt$ units of labor at cost $bjdt$ and leads to success with probability jdt. When the Northern firm is successful in forming a JV with the Southern firm, it receives a Northern share of market value of a JV (V_H^{JVN1}). V_H^{JVN1} is derived from the Northern optimal JV contract. We will discuss how to derive V_H^{JVN1} in more details later on in the paper. If the Northern firm decides not to transfer high-quality technology and product to a JV, it attains market value of V_L^1. The Northern firm

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[1] Adaptation occurs in the South.

[2] The Northern technology transferred to the South through joint venture requires additional resources used in adaptation. However, technology transferred through licensing may or may not involve additional resources used in adaptation. That is a licensor just sells its technology to Southern licensee without any cost other than transportation cost.

chooses the joint venture intensity by equalizing the capital gain, $V_H^{JVN1} - V_L^1$, to the cost of joint venture, b. The equilibrium condition of a joint venture is

$$V_H^{JVN1} - V_L^1 \le b, j > 0 \Leftrightarrow V_H^{JVN1} - V_L^1 = b \tag{6}$$

Combining (5) and (6), we obtain a joint equilibrium condition as follow.

$$\eta >, j > 0 \Leftrightarrow V_H^{JVN1} = b + wa \tag{7}$$

Finally, we assume that an innovative activity is significantly more difficult than an adaptive activity. Thus, an innovative activity requires more resources compared to an adaptive activity does. That is $a > b$.

Production

By the assumption of two types of consumers and separating equilibrium[3], two quality levels of each product are sold at any point of time. I normalize the unit of labor requirement in production of both goods to 1. Firms in both markets engage in Bertrand price competition and use limit-pricing strategy to prevent entry. There are two active firms in L market, a Northern leader and a JV. A Northern leader produces high-quality product and set the price, $p_L^1 = \lambda^A \lambda^B$, to prevent entry of northern followers who have an access to a one-quality level below. A Northern leader has a marginal cost, w. The demand for high-quality product is $\frac{E^B}{\lambda^A \lambda^B}$. In addition, let $\delta^A = \frac{1}{\lambda^A}$ and $\delta^B = \frac{1}{\lambda^B}$. An instantaneous profit for a Northern leader is

$$\pi_L^1 = (1 - w\delta^A \delta^B)E^B \tag{8}$$

[3] The condition for separating equilibrium is shown in Appendix A.

A JV produces low-quality product and sets the price, $p_L^{JV} = \lambda^A$ to prevent entry. A low-quality JV has a marginal cost equal 1. Thus, a Northern firm has a cost saving incentive to transfer its technology and production to a JV. The demand for low-quality product is $\frac{E^A}{\lambda^A}$. An instantaneous profit for a JV is

$$\pi_L^{JV} = (1-\delta^A)E^A \tag{9}$$

Let α_L be the fraction of an instantaneous profit of a low-quality JV allocated to the Northern partner. Let $1-\alpha_L$ be the fraction of an instantaneous profit of a low-quality JV allocated to Southern partner. Later on we will show that the fraction of an instantaneous profit is exactly the same as the fraction of a value of a JV. The optimal fraction of a value of a JV allocated to the Northern partner, α_L *, is a result of the Northern optimal joint venture contract discussed later on in the paper. Thus, an instantaneous profit for the Northern partner is

$$\pi_L^{JVN} = \alpha_L \pi_L^{JV} = \alpha_L(1-\delta^A)E^A \tag{10}$$

An instantaneous profit for the Southern partner is

$$\pi_L^{JVS} = (1-\alpha_L)\pi_L^{JV} = (1-\alpha_L)(1-\delta^A)E^A \tag{11}$$

There are two active firms in H market, a high-quality JV and a low-quality JV. A Northern leader transfers the production of high-quality product to a high-quality JV in the South. A high-quality JV sets the price, $p_H^{JV} = \lambda^B\lambda^A$ and has a marginal cost equal1. The demand for high-quality product is $\frac{E^B}{\lambda^A\lambda^B}$. An instantaneous profit for a JV is

$$\pi_H^{JV1} = (1-\delta^A\delta^B)E^B \tag{12}$$

Let α_H be the fraction of an instantaneous profit of a high-quality JV allocated to the Northern partner. Let $1-\alpha_H$ be the fraction of an instantaneous profit of a high quality JV allocated to the Southern partner. An instantaneous profit for the Northern partner and Southern partner are follows:

$$\pi_H^{JVN1} = \alpha_H \pi_H^{JV1} = \alpha_H (1-\delta^A \delta^B) E^B \tag{13}$$

$$\pi_H^{JVS1} = (1-\alpha_H)\pi_H^{JV1} = (1-\alpha_H)(1-\delta^A \delta^B) E^B \tag{14}$$

A low-quality JV produces a low-quality product. A low-quality JV sets the price, $p_H^{JV2} = \lambda^A$ and has marginal cost equal 1. An instantaneous profit for a JV is

$$\pi_H^{JV2} = (1-\delta^A) E^A \tag{15}$$

An instantaneous profit for the Northern partner is

$$\pi_H^{JVN2} = \alpha_H \pi_H^{JV2} = \alpha_H (1-\delta^A) E^A \tag{16}$$

An instantaneous profit for the Southern partner is

$$\pi_H^{JVS2} = (1-\alpha_H)\pi_H^{JV2} = (1-\alpha_H)(1-\delta^A) E^A \tag{17}$$

Note that low-quality JVs in both markets are located in the South. Both firms have the same cost and set the same price. As a result, an instantaneous profit of both firms are the same, $\pi_L^{JV} = \pi_H^{JV2}$. Moreover, Northern share of an instantaneous profit of a JV in both markets are the same, $\pi_L^{JVN} = \pi_H^{JVN2}$. Similarly, Southern share of an instantaneous profit of a JV in both market are the same, $\pi_L^{JVS} = \pi_H^{JVS2}$.

A Northern firm that successful at innovation in L market gains the value of a Northern leader, V_L^1. A Northern leader faces the risk of innovation from followers. A successful innovation replaces the former high-quality product with the new high-quality product. As a result, the production of the former high-quality product is transfer to a JV.

In addition, a Northern leader also faces the risk that the current high-quality product might be transferred to a JV.

The value of a Northern leader in the L market is

$$V_L^1 = \frac{\pi_L^1 + \eta V_L^{JVN} + jV_H^{JVN1}}{(\rho + \eta + j)} \tag{18}$$

where V_L^{JVN} is the market value of a low-quality JV hold by a Northern partner in L market, and V_H^{JVN1} is the market value of a high-quality JV hold by a Northern partner in H market.

A low-quality JV in L market faces the risk of successful innovation and the risk that high-quality technology being transfer to a JV. If high-quality technology is transferred to a JV, a low-quality JV in L market becomes a low-quality JV in H market. Moreover, a low-quality JV in L market is out of the market whenever there is a successful innovation.

The value of a low quality JV in L market is

$$V_L^{JV} = \frac{\pi_L^{JV} + jV_H^{JV2}}{(\rho + \eta + j)} \tag{19}$$

In H market, a Northern leader transfers production of high-quality product to a JV. A high-quality JV faces the risk of innovation by followers. A high-quality JV in H market becomes a low-quality JV in L market whenever there is a successful innovation.

The value of a high-quality JV in H market is

$$V_H^{JV1} = \frac{\pi_H^{JV1} + \eta V_L^{JV}}{(\rho + \eta)} \tag{20}$$

A low-quality JV in H market faces only the risk of innovation. A low-quality JV is out of the market whenever there is a successful innovation. The value of a low-quality JV in H market is

$$V_H^{JV2} = \frac{\pi_H^{JV2}}{(\rho + \eta)} \tag{21}$$

Since $\pi_L^{JV} = \pi_H^{JV2}$, we can show that $V_L^{JV} = V_H^{JV2} = \dfrac{\pi_H^{JV2}}{(\rho + \eta)}$ (22)

The Northern share of a high-quality JV in H market is

$$V_H^{JVN1} = \frac{\pi_H^{JVN1} + \eta V_L^{JVN}}{(\rho + \eta)}. \tag{23}$$

The Northern share of a low-quality JV in L market is

$$V_L^{JVN} = \left(\frac{\pi_L^{JVN} + jV_H^{JVN2}}{\rho + \eta + j} \right) \tag{24}$$

The Northern share of a low-quality JV in H market is

$$V_H^{JVN2} = \frac{\pi_H^{JVN2}}{\rho + \eta} \tag{25}$$

Substituting (13), (24) and (25) into (23), we get the Northern share of a high-quality JV in H market

$$V_H^{JVN1} = \alpha_H \left(\frac{\pi_H^{JV1} + \eta V_L^{JV}}{\rho + \eta} \right) = \alpha_H V_H^{JV1} \tag{26}$$

The Northern share of a high-quality JV is equal to the fraction α_H multiplied by the value of a high-quality JV. Similarly, we can show that the Southern share of a high-quality JV in H market is equal to a fraction $(1 - \alpha_H)$ multiplied by the value of a low-quality JV.

$$V_H^{JVS1} = 1 - \alpha_H \left(\frac{\pi_H^{JV1} + \eta V_L^{JV}}{\rho + \eta} \right) = (1 - \alpha_H) V_H^{JV1} \tag{27}$$

The Northern share of a low-quality JV in L market is

$$V_L^{JVN} = \frac{\pi_L^{JVN}}{\rho + \eta} = \alpha_L \frac{\pi_L^{JV}}{\rho + \eta} = \alpha_L V_L^{JV} \tag{28}$$

The Southern share of a low-quality JV in L market is

$$V_L^{JVS} = \frac{\pi_L^{JVS}}{\rho + \eta} = (1 - \alpha_L) \frac{\pi_L^{JV}}{\rho + \eta} = (1 - \alpha_L) V_L^{JV} \tag{29}$$

The Northern and Southern shares of a JV in H and L market are the fraction α_H multiplied by the value of a low-quality JV and $(1 - \alpha_H)$ multiplied by the value of a low-quality JV respectively.

Resource Constraints

Let n denote the extent of high-quality JV market (the proportion of products produced in H market). Let $(1 - n)$ denote the extent of low-quality JV market (the proportion of products produced in L market). L^N and L^S denote Northern labor supply and Southern labor supply respectively. In the labor market equilibrium, the demand for labor must equal to the supply of labor in each country.

In the North, labors are allocated to innovation and the production of high-quality product in L market. Northern labor market clearing condition is

$$a\eta + (1 - n) E f^B \delta^A \delta^B = L^N \tag{30}$$

The first term is Northern labor demand for innovation in both markets. The second term is Northern labor demand for production in L market.

In the South, labors are allocated to adaptation, production of low-quality product in both markets, and production of high-quality product in H market.

The Southern labor market clearing condition is

$$bj(1-n) + Ef^{A}\delta^{A} + nEf^{B}\delta^{A}\delta^{B} = L^{S} \tag{31}$$

The first term is Southern labor demand for adaptation of new high technology. The second term is Southern labor demand for the production of low-quality product in both markets. The last term is Southern labor used in the production of high-quality product in H market.

Contractual Design under Asymmetric Information and Imitation Risk

The coexistence of high-quality and low-quality product in the model allows for the asymmetric information in joint venturing. Under asymmetric information, Northern partners have private information about the quality level of their technology. Southern partners cannot observe the quality of technology without direct inspection. In the model, Northern partners face two problems (asymmetric information and imitation risk). Due to an imitation risk, a high-quality Northern firm cannot inform a potential Southern partner of the quality of technology without revealing its technology. As a result, a low-quality Northern firm has an incentive to pretend to be a high-quality Northern firm. A high-quality Northern partner faces imitation risk after technology is transfers to a JV. A high-quality Northern partner has to design a joint venture contract that not only informs a southern partner of the true quality of technology but also the share of value of a JV that prevents imitation.

Following Gallini and Wright (1990), I focus on separating equilibrium contracts in a signaling game. The game has three stages. In the first state, a Northern partner offers a take-it-or-leave-it joint venturing contract to a Southern partner. A Southern partner cannot observe the type of technology at the time being. A Southern partner accepts or rejects the offer. In the second stage, if a Southern partner accepts the contract, a Northern partner transfers its technology, and a Southern partner observes the type of technology by inspection. In the third stage, a Southern partner decides whether to imitate or not. If a Southern partner imitates, it earns monopoly profits. If a Southern partner does not imitate, it gets the share of the value of a JV specified in the contract.

The low-quality Northern partner faces the imitation problem. It has to decide a contract that discourages imitation. The low-quality Northern partner maximizes its share of a JV, $V_L^{JVN} = \alpha_L V_L^{JV}$. Since there are two kinds of technology, let c_L and c_H denote the marginal cost of imitating low-quality and high-quality product with respectively. $C(k)$ is the imitation cost by the Southern partner, where k is the degree of Southern IPRs protection and $C'(k) > 0$. Let $C(k) = c_n k$, where n = L and H. Moreover, the marginal cost of imitating high-quality product is higher than the marginal cost of imitating low-quality product. That is $c_H > c_L$.

The low-quality Northern partner's maximization problem is to choose the fraction of the value of a JV $(0 < \alpha_L < 1)$ to maximize the Northern share of value of a low-quality JV.

$$Max(\alpha_L V_L^{JV}) \tag{32}$$

s.t. $\alpha_L V_L^{JV} \le V_L^{JV}$ (feasibility)

$(1-\alpha_L)V_L^{JV} \ge V_L^{JV} - kc_L$ (no imitation)

$0 < \alpha_L < 1$

The feasibility constraint is that the Northern share of a JV is less than or equal to the value of the producing firm in L market (a JV). The no imitation constraint is that the southern share of market value with no imitation is greater than or equal to net gain from imitation. The restriction on the fraction of the value of a JV allocated to the Northern partner, $0 < \alpha_L < 1$, guarantees that the feasibility constraint is hold with inequality. That is the feasibility constraint is not binding. The Lagrangian equation for the low-quality Northern partner's problem is

$$L = \alpha_L V_L^{JV} + \varepsilon(V_L^{JV} - \alpha_L V_L^{JV}) + \upsilon(kc_L - \alpha_L V_L^{JV}) \tag{33}$$

The Kuhn-Tucker Conditions are:

$$V_L^{JV}(1-\varepsilon-\upsilon) \le 0 \qquad \text{C.S.} \quad \alpha \ge 0 \tag{34}$$

$$V_L^{JV} - \alpha_L V_L^{JV} \le 0 \qquad \text{C.S.} \quad \varepsilon \ge 0 \tag{35}$$

$$kc - \alpha_L V_L^{JV} \le O \qquad \text{C.S.} \quad \upsilon \ge 0 \tag{36}$$

C.S. denotes the complementary-slackness condition.

Four exhaustive cases are considered.

Case 1: $0 < \alpha_L < 1, \varepsilon > 0, \upsilon = 0$

Case 2: $0 < \alpha_L < 1, \varepsilon > 0, \upsilon > 0$

Case 3: $0 < \alpha_L < 1, \varepsilon = 0, \upsilon > 0$

Case 4: $0 < \alpha_L < 1, \varepsilon = 0, \upsilon = 0$

Case 1, 2, and 4 can be ruled out due to the restriction on α_L and contradictions among conditions. The solution for case 3 is as follows:

From (34) and $\varepsilon = 0$, we have $\upsilon = 1$ (37)

From (35), we have $0 < \alpha_L < 1$ (38)

From (36),we have $\alpha_L * = \frac{kc_L}{V_L^{JV}}$ (39)

Substituting $\alpha_L * = \frac{kc_L}{V_L^{JV}}$ into (32), the maximum Northern market value of a low-quality JV is $V_L^{JVN} = kc_L$ (40)

The solution to this problem is that the optimal Northern share of a low-quality JV is $\alpha_L * = \frac{kc_L}{V_L^{JV}} < 1$. The rationality constraint is not binding, but the non-imitation constraint is binding. The Northern share of a JV's market value is an increasing function of Southern level of intellectual property right protection $(\frac{\partial \alpha_L *}{\partial k} > 0)$. The stronger the Southern IPR is, the larger the share of Northern partner. On the other hand, the Southern share of a JV decreases when the Southern IPR is stronger $(\frac{\partial(1-\alpha_L *)}{\partial k} < 0)$. The Northern share of a low-quality JV is equal to the cost of imitating the low-quality product, $V_L^{JVN} = kc_L < V_L^{JV}$. Thus, the Northern partner is unable to extract the whole value of a JV (the monopoly rent) from the Southern partner. Transferring technology through a JV requires the high-quality Northern firm to give up monopoly rent in order to discourage imitation. In addition, The Northern share of a JV is also a decreasing function of the Southern strength of intellectual property right $(\frac{\partial V_L^{JVN}}{\partial k} > 0)$. The stronger the Southern intellectual property right is, the larger the Northern share of a JV.

The high-quality Northern partner faces both asymmetric information problem and imitation. On one hand, the Northern firm has to signal the true quality of its technology with out revealing its type of technology. The Northern firm has to distinguish its quality of technology from a low-quality JV. On the other hand, the Northern share of a JV value must discourage imitation after technology has been transferred. The high-quality Northern partner maximizes its share of a high-quality JV (V_H^{JVN1}) by choosing the fraction of the value of a high-quality JV allocated to the Northern partner ($0 < \alpha_H < 1$).

The high-quality Northern partner's maximization problem is

$$Max(\alpha_H V_H^{JV1}) \tag{41}$$

s.t. $\alpha_H V_H^{JV1} \leq V_H^{JV1}$ (feasibility)

$\alpha_H V_H^{JV1} \geq kc_H$ (no imitation)

$\alpha_H V_H^{JV2} \leq V_H^{JV2}$ (separation)

$0 < \alpha_H < 1$

The separation constraint guarantees that a low-quality JV has no incentive to pretend to be a high-quality Northern firm. The restriction $0 < \alpha_H < 1$ guarantees that the feasibility and separation constraints are hold with inequality. Thus, the feasibility and separation constraints are not binding.

The Largrangian equation for the low-quality Northern partner's problem is

$$L = \alpha_H V_H^{JV1} + \varepsilon(V_H^{JV1} - \alpha_H V_H^{JV1}) + \upsilon(kc_H - V_H^{JV1}) + \beta(V_H^{JV2} - \alpha_H V_H^{JV2}) \tag{42}$$

The Kuhn-Tucker Conditions are:

$$V_H^{JV1}(1-\varepsilon-\upsilon) - \beta V_H^{JV2} \leq 0 \qquad \text{C.S.} \quad \alpha_H \geq 0 \tag{43}$$

$$V_H^{JV1} - \alpha_H V_H^{JV1} \geq 0 \qquad \text{C.S.} \quad \varepsilon \geq 0 \tag{44}$$

$$kc_H - \alpha_H V_H^{JV1} \geq O \qquad \text{C.S.} \quad \upsilon \geq 0 \tag{45}$$

$V_H^{JV2} - \alpha_H V_H^{JV2} \geq 0$ C.S. $\beta \geq 0$ (46)

Eight exhaustive cases are considered.

Case 1: $0 < \alpha_H < 1, \varepsilon = 0, \upsilon = 0, \beta = 0$

Case 2: $0 < \alpha_H < 1, \varepsilon = 0, \upsilon = 0, \beta > 0$

Case 3: $0 < \alpha_H < 1, \varepsilon = 0, \upsilon > 0, \beta > 0$

Case 4: $0 < \alpha_H < 1, \varepsilon = 0, \upsilon > 0, \beta = 0$

Case 5: $0 < \alpha_H < 1, \varepsilon > 0, \upsilon = 0, \beta = 0$

Case 6: $0 < \alpha_H < 1, \varepsilon > 0, \upsilon > 0, \beta = 0$

Case 7: $0 < \alpha_H < 1, \varepsilon > 0, \upsilon = 0, \beta > 0$

Case 8: $0 < \alpha_H < 1, \varepsilon > 0, \upsilon > 0, \beta > 0$

Case 1, 2, 3, 5, 6, 7, and 8 can be ruled out by the restriction on α_H and the contradictions among conditions. The solution for case 4 is as follows:

From (43), $\varepsilon = 0$ and $\beta = 0$, we have $\upsilon = 1$. (47)

From (44) and (46), we have $0 < \alpha_H * < 1$ (48)

From (45), we have $\alpha_H * = \dfrac{kc_H}{V_H^{JV1}}$ (49)

Thus, the maximum Northern share of a high-quality JV is

$V_H^{JVN1} = \alpha_H * V_H^{JV1} = kc_H$ (50)

In this case, the solution of the Northern partner's maximization problem is $\alpha_H * = \dfrac{kc_H}{V_H^{JV1}}$. The rationality constraint and the separation constraint are not binding, but the non-imitation constraint is binding. The fraction of the value of a high-quality JV allocated to the Northern partners is an increasing function of the Southern strength of intellectual property right ($\frac{\partial \alpha_H *}{\partial k} > 0$). On the other hand, The fraction of the value of a high-quality JV allocated to the Southern partner is a decreasing function of the Southern strength of intellectual property right ($\frac{\partial (1-\alpha_H *)}{\partial k} < 0$). In addition, the maximum Northern market value of a high-quality JV is less than the market value of a high-quality JV (the monopoly rent). That is $V_H^{JVN1} = kc_H < V_H^1$. Transferring technology through a JV requires the high-quality Northern firm to give up some monopoly rent in order to signal the true quality of technology and to discourage imitation. In addition, the Northern share of a high-quality JV is an increasing function of Southern level of intellectual property right ($\frac{\partial V_H^{JVN1}}{\partial k} > 0$). The stronger the Southern intellectual property right is, the larger the Northern market value of a high-quality JV.

Steady-State Equilibrium

The steady-state condition is that measures of product in each market remain constant. In other words, the flows of product out of H market (the flows into L market) must be equal to the flows of product into H market (the flows out of L market). Products flow into L market via innovation in L market, $\eta(1-n)$, and innovation in H market, ηn. Products flow out of L market via innovation in L market, $\eta(1-n)$, and transferring technology through a JV to H market, $j(1-n)$.

The steady state condition is

$$j(1-n) = \eta n \tag{51}$$

The first term in (51) represents the net flows of product out of L market L, and the second term represents the net flows of product into L market.

Since innovation targets both markets, the rate of innovation ($\eta(n_H + n_L)$) is the intensity of innovation (η). $j(1-n)$ is the rate of joint venture. Using (51), the rate of joint venture relative to the rate of innovation equal to the extent of high-quality joint venture market (n).

$$\frac{j(1-n)}{\eta} = \frac{n\eta}{\eta} = n \tag{52}$$

Thus, factors that increase the rate of joint venture relative to the rate of innovation increase the extent of high-quality joint venture market.

We are trying to solve for four endogenous variables (η, n, w and E) from a system of four equations (Northern and Southern resource constraints and innovation and joint venture equilibrium equations). First, we substitute the steady state equilibrium condition (51) into the Southern resource constraint (31), we obtain the steady- state Southern resource constraint as follow.

$$bn\eta + Ef^{A}\delta^{A} + nEf^{B}\delta^{A}\delta^{B} = L^{S} \tag{53}$$

Then, we use the Northern resource constraint (30) and the Southern resource constraint (31) to solve for E as a function of two endogenous variables (n and η), and exogenous variables.

$$E = \frac{L^{N} + L^{S} - bn\eta - a\eta}{\delta^{A} f^{A} + \delta^{A}\delta^{B} f^{B}} \tag{54}$$

Then substituting (54) into (30), we have a joint resource constraint equation in which contain two endogenous variables (n and η) as follow.

$$a\eta + (1-n)(L^N + L^S - a\eta - bn\eta)\phi = L^N \tag{55}$$

,where $\phi = \dfrac{f^B\delta^A\delta^B}{f^B\delta^A\delta^B + f^A\delta^A} < 1$

Taking total derivative of (55), we obtain the relation ship between the rate of innovation, η and the extent of high-quality joint venture market, n.

$$\frac{d\eta}{dn} = \frac{(L^N + L^S - (a-b+2bn)\eta)\phi}{a-(1-n)(a+bn)\phi} > 0 \tag{56}$$

$$\frac{d^2\eta}{dn^2} = \frac{\phi\begin{pmatrix} b^2\eta n + a\phi(L^N + L^S - 2n(L^N + L^S) + b\eta(1-2n+2n^2)) \\ + a(-\phi(L^N + L^S) + 2b\eta(-1+n\eta)) \end{pmatrix}}{\left(a(-1+n)n\phi + b(1+(-1+n)\phi)\right)^2} \tag{57}$$

$$\frac{d^2\eta}{dn^2} > or < 0$$

Thus, there is a positive relationship between the extent of high-quality joint venture market and the rate of innovation. This is because an increase in the extent of high-quality joint venture market frees up Northern labor in a production of high-quality product sector. As a result, more Northern labor are used in R&D sector.

Using (50), (6) and (5), we can solve for the equilibrium wage rate as follow.

$$w = \frac{kc_H - b}{a} \tag{58}$$

Substituting equations (6), (39) and (51) into (18), we have

$$V_L^1 = \frac{\pi_L^1 + \eta kc_L + \dfrac{n\eta}{(1-n)}b}{\rho + \eta} \tag{59}$$

Substituting (59) and (8) into (6), we have the following joint venture equilibrium condition as a function of three endogenous variable $(n, w$ and $\eta)$ and exogenous variables.

$$(\rho+\eta)kc_H = (\frac{L^N + L^S - an - bn\eta}{f^B\delta^A\delta^B + f^A\delta^A}) f^B(1 - w\delta^A\delta^B) + (\rho + \frac{\eta}{1-n})b + \eta kc_L \qquad (60)$$

Substituting (58) into (60), we have the following joint valuation gives the relationship between two endogenous variables $(n$ and $\eta)$ when the joint venture equilibrium condition and the free entry condition are satisfied.

$$(\rho+\eta)kc_H = (\frac{L^N + L^S - an - bn\eta}{f^B\delta^A\delta^B + f^A\delta^A}) f^B(1 - (\frac{kc_H - b}{a})\delta^A\delta^B) + (\rho + \frac{\eta}{1-n})b + \eta kc_L \qquad (61)$$

Taking total derivative of (61), we obtain the relation ship between the rate of innovation, η and the extent of high-quality joint venture market, n.

$$\frac{d\eta}{dn} = -\frac{\dfrac{b\eta}{(1-n)^2} + \dfrac{bf^B(1-(\frac{kc_H - b}{a})\delta^A\delta^B)\eta}{f^A\delta^A + f^B\delta^A\delta^B}}{(c_H - c_L)k + \dfrac{b}{1-n} + \dfrac{f^B(a+bn)(1-(\frac{kc_H - b}{a})\delta^A\delta^B)}{f^A\delta^A + f^B\delta^A\delta^B}} < 0 \qquad (62)$$

$$\frac{d^2\eta}{dn^2} = b\left(\frac{f^B(1-\delta^A\delta^B(\frac{kc_H - b}{a})}{f^A\delta^A + f^B\delta^A\delta^B} + \frac{-1+n-2\eta}{(-1+n)^3}\right) > 0 \qquad (63)$$

Thus, when the joint venture equilibrium and the free entry condition are satisfied, the extent of a high-quality joint venture is negatively related to the rate of innovation. Equation (55) and (60) form the system of equation that could be solved for variables of interest $(n$ and $\eta)$. We plot the combinations of n and η that satisfy equation (55) as the RC curve. We plot the combinations of n and η that satisfy equation (60) as the VC curve. The RC curve has a positive slope, and the VC curve has a negative slope. The intersection of RC and VC determines the steady-state equilibrium rate of innovation and the extent of high-quality JV market. The curve RC and VC are shown in picture 2.

Intellectual Property Rights, Innovation and Technology Transfer

In this section, we study how a strengthening of Southern intellectual property right affects the rate of innovation and the extent of high-quality JV market. In the model, the change in Southern intellectual property right affects only VC curve. We determine the shift of VC curve by solving a system of two linear equations, shown in Appendix B, for $\frac{\partial \eta}{\partial k}$ and $\frac{\partial n}{\partial k}$. As shown in Appendix B, $\frac{\partial \eta}{\partial k} > 0$ and $\frac{\partial n}{\partial k} > 0.$ Therefore, a stronger Southern intellectual property right shifts VC curve to the right (from VC1 to VC 2) but leaves RC curve intact. The shift of VC is shown in picture 2.

Proposition 1. *If Southern intellectual property right is stronger, both the rate of innovation and the extent of high-quality JV would increase.*

The intuition behind Proposition 1 is as follow. A stronger Southern IPR increases the Northern share of a JV and thus encourages Northern firms to transfer more technology and production through JVs. In addition, since productions of high-quality product are transferred to the South, more resources are available for innovation activities in the North. Therefore, a stronger Southern IPR increases the rate of innovation.

Intellectual Property Rights, Aggregate Expenditure and Relative Wage

Using the steady-state equilibrium relative wage (58), we can show that $\frac{dw}{dk} > 0$

We find the effect of the Southern IPR on the aggregate expenditure by totally differentiating (54).

$$\frac{dE}{dk} = \frac{\partial E}{\partial n}\frac{\partial n}{\partial k} + \frac{\partial E}{\partial \eta}\frac{\partial \eta}{\partial k} < 0$$

Since, $\frac{\partial E}{\partial n}$ and $\frac{\partial E}{\partial \eta} < 0$ as shown in Appendix B.

Proposition 2. *As Southern intellectual property right is stronger, the relative wage increases. However, the aggregate expenditure decreases.*

The intuition behind Proposition 2 is the follow. When Southern IPR is stronger, there are two opposite effects on the relative wage. On one hand, a stronger Southern IPR increases the rate of innovation. This effect would raise the demand for Northern labor (used in innovative activities) and the Northern relative wage increases. On the other hand, a stronger IPR increases the Northern share of market value of a JV and thus, more Northern production is transferred to a JV. This would raise the Southern demand for labor (used in adaptive activities and the production of new good) resulting in a decrease in the relative wage. In this model, the first effect dominates the second effect. Therefore, as Southern IPR is stronger, the relative wage increases.

Modes of Technology Transfer under Asymmetric Information and Imitation Risk

In this section, I derive conditions under which JV is a more preferred channel of transfer to Licensing under asymmetric information and imitation risk. Two types of licensing contract are studied; a contract with an upfront fixed fee and output royalties as in Gallini and Wright (2001) and a contract with an upfront fixed fee and the royalty fee proportional to the licensee's monopoly rent as in Yang and Maskus (2002). The optimal licensor's rent from the former contract is shown in appendix C, and the optimal licensor's rents from the later contract are shown in appendix D. We simply assume that a Northern multinational prefers a JV as a mode of technology transfer if the Northern share of a JV is greater than the licensor's rent. A Northern Multinational prefers licensing over a JV as a mode of technology transfer if the licensor's rent is greater than the Northern share of a JV. Table 1 presents the Northern value of a JV, the licensor's rent under a licensing contract with output royalties and (LO) the licensor's rent under a licensing contract with proportional royalty fee (LP).

Table 1

Contract / Technology Transfer	JV Contract	Licensing Contract (Fixed fee & Output Royalties, LO)	Licensing Contract (Fixed fee & Proportional Royalty fee, LP)
Low-Quality Technology Transfer	$V_L^{JVN} = kc_L < V_H^{JV2}$	$F_L^{LO} = V_L^{LO} = V_H^{JV2}$	$F_L^{LP} = V_L^{LP} = V_H^{JV2}$

High-Quality Technology Transfer	$V_H^{JVN1} = kc_H$	$V_H^{LO} = V_L^{LO} + kc_{HL}$	$V_H^{LP} = V_L^{LP} + \theta kc_{HL}$ where $0 < \theta < 1$

In the case of low-quality transfer, both licensing contracts allow a licensor to extracts full monopoly rent by charging an up-front fixed fee equal to monopoly rent. A licensor under (LO) and (LP) get monopoly rent V_L^{LO} and V_L^{LP} respectively. Note that in the model, $V_L^{LO} = V_L^{LP} = V_H^{JV2}$. However, in a JV contract, a Northern partner has to share the value of a JV with a Southern partner. As a result, a Northern partner cannot extract full monopoly rents. A Northern share of a JV (V_L^{JVN}) is equal to kc_L and less than V_H^{JV2}.

Proposition 3. *In the case of low-quality technology transfer, licensing contracts are more preferred than a JV contract. That is* $V_L^{LO} = V_L^{LP} = V_H^{JV2} > V_L^{JVN}$.

In the case of high-quality technology transfer, all contracts considered here do not allow a Northern multinational to capture full monopoly rent. Under asymmetric information and imitation risk, a Northern partner has to share rent with a Southern partner. Similarly, as shown in Gallini and wright (1990) and Yang and Maskus (2002), licensors under both contracts cannot get full monopoly rent. From table 1, the licensor's rent under LO contract is $V_H^{LO} = V_L^{LO} + kc_{HL}$, where c_{HL} is the imitation cost under a licensing contract. Assume that the cost of imitation under a LO contract is the same as the one under a LP contract. The licensor's under LP contract is $V_H^{LO} = V_L^{LO} + \theta kc_{HL}$. The Northern share of a JV is $V_H^{JVN1} = kc_H$.

Proposition 4. *In the case of high-quality technology transfer, if the cost of imitation under a licensing contract is the same as the cost of imitation under a JV,* $c_H = c_{HL}$*, then* $V_H^{LO} > V_H^{JVN1}$ *and* V_H^{LP}*. In addition,* $V_H^{JNN1} > V_H^{LP}$ *,if* $k > \frac{V_L^{LP} c_H}{(1-\theta)}$.

Proposition 4 says that regardless of the strength of Southern IPRs, a LO contract is the most preferred for a Northern multinational. Moreover, a JV is more preferred than a LP contract when the Southern IPR is sufficiently strong..

Proposition 5. *In the case of high-quality technology transfer, if* $c_H \neq c_{HL}$*, then* $V_H^{LO} > V_H^{LP}$*. In addition,* $V_H^{JVN1} > V_H^{LO}$ *if* $c_H - c_{HL} > \frac{V_L^{LO}}{k}$*, and* $V_H^{JVN1} < V_H^{LO}$ *if* $c_H - c_{HL} < \frac{V_L^{LO}}{k}$.

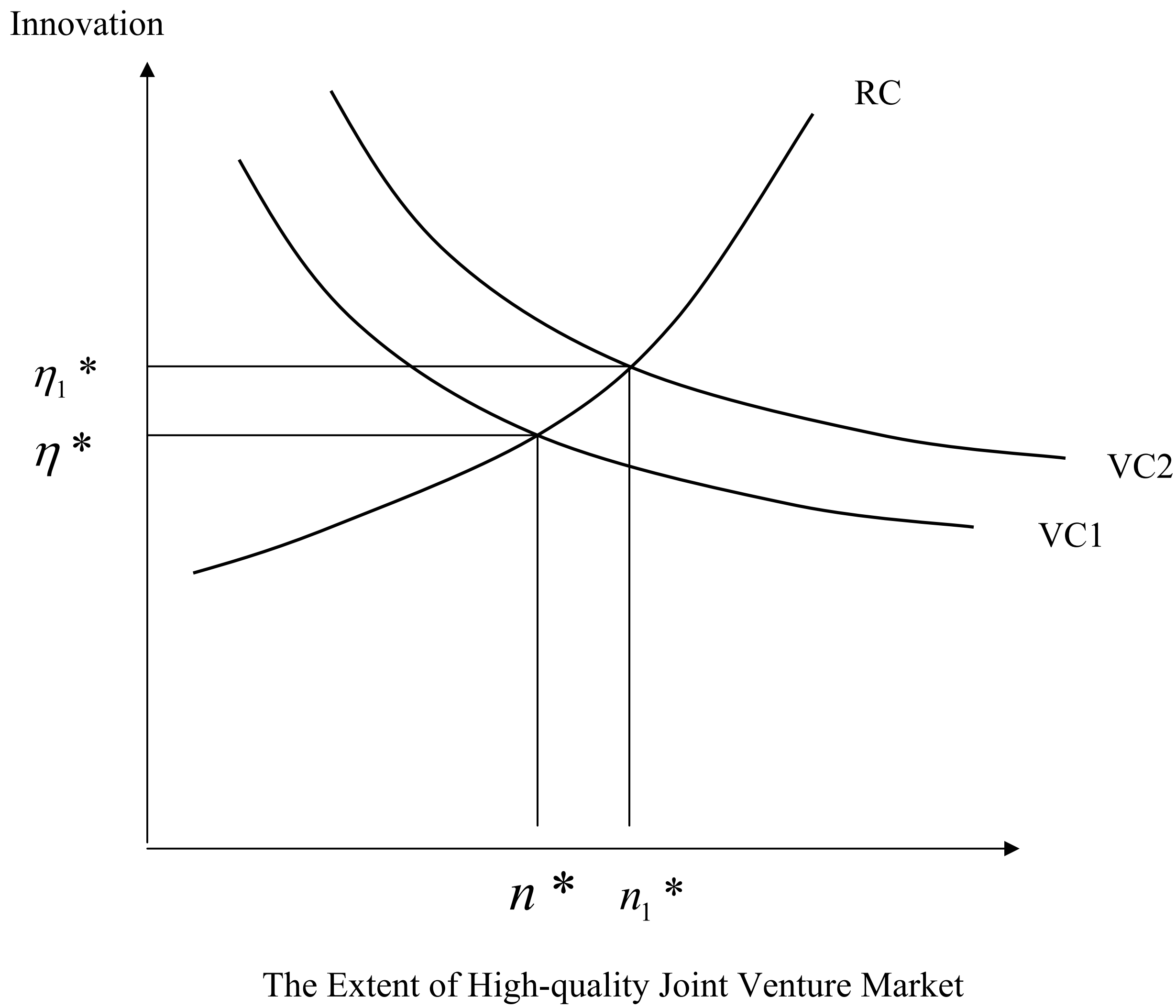
Proposition 5 says that if the cost of imitation under a JV contract is not equal to the cost of imitation under a licensing contract, A L0 contract is more preferred than a LP contract. Moreover, a preferred mode of technology transfer is determined by the costs of imitation. If the cost of imitation under a JV contract is sufficiently high relative to the cost of imitation under a licensing contract, a JV is the preferred mode of technology transfer by a Northern multinational. This might happen when a Northern partner has a control over the use of technology and provides a Southern partner an incomplete access to its technology. It might be very difficult for the South to imitate. Thus, the cost of imitation under a JV contract might be sufficiently high, and a JV might be the preferred mode of technology transfer. In contrast, if the cost of imitation under a LO contract is sufficiently high relative to the cost of imitation under a JV contract, licensing under LO contract is the preferred mode of technology transfer. This might happen if a licensor can find the way keep the secret of it technology and transfers only how to use the technology to produce goods to the South. As a result, the cost of imitation under a licensing contract might be sufficiently high, and a licensing contract might be the preferred mode of technology transfer.

Conclusion

In this paper, I develop a quality ladder product cycle model with two quality levels to examine the effects of intellectual property rights (IPRs) protection on the extent of international joint ventures (JVs) and the rate of innovation under asymmetric information and imitation risk. The Northern share of a JV is endogenously determined. An optimal Northern share of a JV is an increasing function of Southern IPRs. With asymmetric information problem and imitation risk, an optimal JV contract involves giving a Southern partner a larger share of a JV when Southern IPRs are weak, and giving a smaller share when Southern IPRs are strong. The results are that stronger Southern IPRs increase the extent of JVs, the rate of innovation and the relative wage.

Comparing our result to the one in Glass and Saggi (2002), although FDI and joint venture are basically foreign direct investment, the impacts of Southern IPRs on these two channels of technology transfer are opposite. In Glass and Saggi (2002), stronger IPRs require more southern resources used in imitation at a given successful rate resulting in fewer resources available for FDI. A decrease in FDI implies that more productions remain in the North resulting in less Northern labor available for innovation. Therefore, the rate of innovation decreases. In our model, imitation is discouraged by the optimal joint venture contract. Thus, there are no resources wasted in imitation. More Southern labors are available for adaptation. Moreover, stronger Southern IPRs increase Northern share of a JV providing an incentive to transfer technology through a JV. Thus, stronger Southern IPRs increase the extent of JV. An increase in an extent of JV implies that more Northern labor are available for innovation, and thus the rate of innovation increases. Our result provides a reason to support the TRIPs agreement in the sense that Southern countries would get more technology transfer if they strengthen their IPRs protection. In addition, stronger Southern IPRs encourage innovation that benefits both Northern and Southern countries.

We analyze conditions under which a JV is a more preferred of technology transfer compared to licensing. In the case of low-quality technology transfer, licensing is more preferred to a JV. This is because the fixed fee specified in a licensing contract allows a licensor to extract the full monopoly rent while a Northern partner has to share the rent with the Southern partner. In the case of high-quality technology transfer, if the imitation cost under a JV contract is the same as the one from licensing contracts, a LO contract is the most preferred mode of technology transfer among three. A JV is more preferred to a LP contract, if southern IPRs are sufficiently strong. When imitation costs under a JV and licensing contracts are different, the preferred mode of technology transfer depends on the imitation costs incurring with a JV and licensing contracts. A JV is a preferred mode of technology transferred if the cost of imitation under a JV is sufficiently high relative to the cost of imitation under licensing contracts.



Picture 2: Steady-State Equilibrium of the Rate of Innovation and the Extent of Joint Venture Market

Appendix A

Condition for Separation

In the L market, if a Northern leader 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 earns instantaneous profits $\pi^S = Ef^B(1-\delta^A\delta^B w)$. Its expected firm value is $V^S = \frac{\pi_L^1+\eta V_L^2}{\rho+\eta}$.

Separation occurs in the L market if $V^S > V^P$. 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 high-quality JV 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

$\pi^S = Ef^B(1-\delta^A\delta^B)$. 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. In addition if, $f^B > \frac{1-\delta^A}{1-\delta^A\delta^B}$, then from 20 and 21, we can show that

$$V_H^{JV1} - V_H^{JV2} = \frac{E\big((\rho+\eta)f^B(1-\delta^A\delta^B) - \rho(1-f^B)(1-\delta^A)\big)}{(\rho+\eta)^2} > 0$$

Appendix B

The signs of $\frac{\partial \eta}{\partial k}$ and $\frac{\partial n}{\partial k}$ are determined by the solution to the system

$$\begin{bmatrix} \frac{\partial F^1}{\partial n} & \frac{\partial F^1}{\partial \eta} \\ \frac{\partial F^2}{\partial n} & \frac{\partial F^2}{\partial \eta} \end{bmatrix} \begin{bmatrix} \frac{\partial n}{\partial k} \\ \frac{\partial \eta}{\partial k} \end{bmatrix} = \begin{bmatrix} \frac{\partial F^1}{\partial k} \\ \frac{\partial F^2}{\partial k} \end{bmatrix}$$

where

F^1 is $a\eta + (1-n)(L^N + L^S - a\eta - bn\eta)\phi - L^N = 0$

F^2 is

$$(\rho+\eta)kc_H - (\frac{L^N + L^S - an - bn\eta}{f^B\delta^A\delta^B + f^A\delta^A})f^B(1-(\frac{kc_H - b}{a})\delta^A\delta^B) + (\rho + \frac{\eta}{1-n})b + \eta kc_L = 0$$

$$\frac{\partial F^1}{\partial n} = -(L^N + L^S - (a - b + 2bn)\eta)\phi < 0$$

$$\frac{\partial F^2}{\partial n} = a - (1-n)(a+bn)\phi > 0$$

$$\frac{\partial F^1}{\partial \eta} = \frac{b\eta}{(1-n)^2} + \frac{bf^B(1-\left(\frac{kc_H - b}{a}\right)\delta^A\delta^B)\eta}{f^A\delta^A + f^B\delta^A\delta^B} > 0$$

$$\frac{\partial F^2}{\partial \eta} = - = (c_H - c_L)k + \frac{b}{1-n} + \frac{f^B(a+bn)(1-(\frac{kc_H - b}{a})\delta^A\delta^B}{f^A\delta^A + f^B\delta^A\delta^B} > 0$$

$$\frac{\partial F^1}{\partial k} = 0$$

$$\frac{\partial F^2}{\partial k} = (c_H - c_L) + \frac{\delta^A\delta^B c_H f^B(L^N + L^S - a\eta - bn\eta)}{a(\delta^A f^A + \delta^A\delta^B f^B)} + c_H\rho > 0$$

$$|J| = \begin{vmatrix} \frac{\partial F^1}{\partial n} & \frac{\partial F^1}{\partial \eta} \\ \frac{\partial F^2}{\partial n} & \frac{\partial F^2}{\partial \eta} \end{vmatrix} < 0$$

By Cramer's rule

$$\frac{\partial n}{\partial k} = \frac{\begin{vmatrix} 0 & \frac{\partial F^1}{\partial \eta} \\ \frac{\partial F^2}{\partial k} & \frac{\partial F^2}{\partial \eta} \end{vmatrix}}{|J|} > 0$$

$$\frac{\partial n}{\partial k} = \frac{\begin{vmatrix} \frac{\partial F^1}{\partial n} & 0 \\ \frac{\partial F^2}{\partial n} & \frac{\partial F^2}{\partial k} \end{vmatrix}}{|J|} > 0$$

$$\frac{\partial E}{\partial n} = -\frac{bn}{\delta^A f^A + \delta^A\delta^B f^B} < 0$$

$$\frac{\partial E}{\partial \eta} = \frac{-a - bn}{\delta^A f^A + \delta^A\delta^B f^B} < 0$$

Appendix C

Contractual Design of Licensing with an Upfront Fixed Fee and Output Based Royalties (LO contract)

This result follows Gallini and Wright (1990). In the first period, a Northern Licensor offers a LO contract. A Southern licensee accepts or rejects contract. In the second period, if a Southern licensee accepts a LO contract, then a Southern licensee pays upfront fixed fee. Then, the technology is transferred, and a Southern licensee observes the type of technology transferred. In the third period, a southern licensee makes a decision to imitate a Northern product. If a Southern licensee doesn't imitate, then it pays output-based royalties.

Let x_i be the profit maximizing output chosen by the licensee producing with i type of innovation, $i \in \{H, L\}$. F_H^{LO} is the up-front fixed fee when high-quality technology is transferred under LO contract. $P(x_i)$ is the fixed output royalties paid when output exceeds some specified $\tilde{x}$. In a separating equilibrium, the low-quality licensor offers the contract with an upfront fixed fee equal to the licensee's monopoly rent (V_L^{LO}). The monopoly rent for the high-quality production is V_H^1. The imitation cost under LO contract is kc_{HL}, where k is the strength of Southern IPR, and c_{Hl} is the imitation cost.

A high quality licensor's problem is

$$Max\ F_H^{LO} + P(x_H) \tag{1.1}$$

$$\text{s.t.}\quad F_H^{LO} + P(x_H) \le V_H^1 \qquad \text{(feasibility)} \tag{1.2}$$

$$V_H^1 - P(x_H) - F_H^{LO} \ge V_H^1 - kc_{HL} - F_H^{LO} \qquad \text{(no imitation)} \tag{1.3}$$

$$F_H^{LO} + P(x_L) \le V_L^{LO} \qquad \text{(separation)} \tag{1.4}$$

From (1.4), we know that $F_H^{LO} \leq V_L^{LO}$. (1.5)

From (1.3), we know that $P(x_H) \leq kc_{HL}$ (1.6)

From (1.6) and (1.2), $F_H^{LO} + P(x_H) \leq \min(V_L^{LO} + kc_{HL}, V_H^1)$ (1.7)

For $V_H^1 > kc_{HL}$, a contract that satisfies (1.2)-(1.3) is the follow;

$$P(x_H) = kc_{Hl}, F_H^{LO} = \min(V_L^{LO} + kc_{HL}, V_H^1) - kc_{HL} \text{ and } \tilde{x} \text{ is } \int_{\tilde{x}}^{x_H} (mr(x)\text{-}1)dx = kc_{HL}$$

With this contract, the feasibility constraint (1.2) is satisfied

since $\min(V_L^{LO} + kc_{HL}, V_H^1) \leq V_H^1$.

The no imitation constraint (1.3) is satisfied since $P(x_H) = kc_{HL}$

The ex post fee, $P(x_H)$, will make a deceived low-quality licensee produce $\tilde{x}$ and pay zero output royalties to low-quality licensor. The separation constraint (4) is satisfied because $\min(V_L^{LO} + kc_{HL}, V_H^1) - kc_{HL} \leq V_L^{LO}$, if $kc_{HL} < V_H^1 - V_L^{LO}$.

Thus, for $kc_{HL} < V_H^1 - V_L^{LO}$, the licensor's optimal contract leaves some rents with the licensee because $F + P(x_H) = V_H^2 + kc_{HL} < V_H^1$.

Appendix D

Contractual Design of Licensing with an Upfront Fixed Fee and Proportional Royalties (LP contract)

This result follows Yang and Maskus (2202). In the first period, a Northern Licensor offers a LP contract. A Southern licensee accepts or rejects contract. In the second period, if a Southern licensee accepts a LP contract, then a Southern licensee pays upfront fixed fee. Then, the technology is transferred, and a Southern licensee observes the type of technology transferred. In the third period, a southern licensee makes a decision to imitate a Northern product. If a Southern licensee doesn't imitate, then it pays fixed royalties proportional to the Licensee's monopoly rent. In a separating equilibrium, the low-quality licensor offers the contract with an upfront fixed fee equal to the licensee's monopoly rent (V_L^{LP}). Similar to this paper, the licensor maximizes rent subject to feasibility, no imitation, and separation constraint. F_H^{LP} is an upfront fixed fee specified in LP contract. γ the royalty rate.

$$Max \quad F_H^{LP} + \gamma V_H^1 \tag{2.0}$$

s.t. $F_H^{LP} + \gamma V_H^1 \le V_H^1$ (feasibility)

$V_H^1 - \gamma V_H^1 - F_H^{LP} \ge V_H^1 - kc_{HL} - F_H^{LP}$ (no imitation)

$F_H^{LP} + \gamma V_H^1 \le V_L^{LP}$ (separation)

The Lagrangian function for the high-quality licensor's rent maximization problem is as follows:

$$L = F_H^{LP} + \gamma V_H^1 + \varepsilon(V_H^1 - \gamma V_H^1 - F_H^{IP}) + \nu(kc_{HL} - \gamma V_H^1) + \beta(V_L^{LP} - F_H^{LP} - \gamma V_H^1)$$

The Kuhn-Tucker conditions are:

$1 - \varepsilon - \beta \le 0$	C.S.	$F \ge 0$	(2.1)
$V_H^1(1 - \varepsilon - \nu) - \beta V_L^{LO} \le 0$	C.S.	$\gamma \ge 0$	(2.2)
$V_H^1 - F_H^{LP} - \gamma V_H^1 \ge 0$	C.S.	$\varepsilon \ge 0$	(2.3)
$kc_{HL} - \gamma V_H^1 \ge 0$	C.S.	$\nu \ge 0$	(2.4)
$V_L^{LP} - F_H^{LP} - \gamma V_L^{LP} \ge 0$	C.S.	$\beta \ge 0$	(2.5)

,where C.S. denotes the complementary-slackness condition.

Three exhaustive cases are considered

Case 1: $F_H^{LP} > 0$ and $\gamma = 0$; Case 2: $F_H^{LP} = 0$ and $\gamma > 0$; Case 3: $F_H^{LP} > 0$ and $\gamma > 0$.

There are no solutions for Case 1 and Case 3 given that $V_H^1 > V_L^{LP}$ and $kc_{HL} > 0$. Only Case 3 is left. There are eight different sub-cases for Case 3:

(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:

From (2.1) and $\varepsilon = 0$, we get $\beta = 1$.

From (2.2) and $\beta = 1$, we get $\nu = \dfrac{V_H^1 - V_L^{LP}}{V_H^1}$

From (2.3) and $\varepsilon = 0$, we get $F_H^{LP} + \gamma V_H^1 \le V_H^1$

From (2.4) and $\nu > 0$, we get $\gamma = \dfrac{kc_{HL}}{V_H^1}$

From (2.5), $\beta = 1$ and $\gamma = \dfrac{kc_{HL}}{V_H^1}$, we get $F_H^{LP} = V_L^{LP} - kc_{HL}\dfrac{V_L^{LP}}{V_H^1}\gamma$

Thus, the licensor's maximum rents are $F_H^{LP} + \gamma V_H^1 = V_L^{LP} + \theta kc_{HL}$,where $\theta = \dfrac{V_H^1 - V_L^{LP}}{V_H^1}$.

Yang and Maskus (2002) shows in their paper that the licensor's optimal contract leaves some rents with the licensee because. $V_L^{LP} + \theta kc_{HL} < V_H^1$.

References

Gallini N.T. and Wright, 1990. Technology transfer under asymmetric information. *Rand Journal of Economics* 21, 147-160

Glass, A.J., Saggi, K., 2002. Intellectual property rights, foreign direct investment. *Journal of International Economics* 56, 387-410.

Glass, A.J., Saggi, K., 1998. International technology transfer and the technology gap. *Journal of development economics* 55, 369-398.

Glass, A.J., Wu, Xiaodong, 2003. Intellectual property rights and quality improvement. Working Paper, Texas A&M University, College Station, Texas.

Grossman, G.M. and E. Helpman, 1991. *Innovation and growth in the global economy*. Cambridge: MIT Press.

Helpman, P., 1993. Innovation, imitation, and intellectual property right. *Econometrica* 61, 1247-1280

Keith, E.,Maskus, 2000. *Intellectual property rights in the global economy*. Institute of International Economics.

Lai, E.L.C., 1998. International intellectual property rights protection and the rate of product innovation. *Journal of Development Economics* 55, 115-130.

Yang, Guifang and Keith E. Maskus, 2001. Intellectual property rights, licensing and innovation in an endogenous product-cycle model. *Journal of International Economics* 53, 169-187.

Yang, Guifang and Keith E. Maskus, 2002. Intellectual property rights, licensing, and Innovation. Working paper.