REVIEW OF DEVELOPMENT ECONOMICS

RDE Special Issue: MS #, Acceptance Date: May 7, 2015

Intellectual Property Rights and the Quality of Transferred Technology in Developing Countries*

Lei Yang; Yingyi Tsai; Arijit Mukherjee

RRH: IPR and the Quality of Transferred Technology
LRH: Lei Yang, Yingyi Tsai Arijit Mukherjee

Abstract

This paper addresses the effects of a stronger patent system in developing countries on the quality of transferred technology and welfare. We show that a stronger patent system can reduce the quality of licensed technology. The presence of technology licensing may encourage the developing country to adopt a stronger patent system compared to the situation where licensing is not an option.

* Yang: Faculty of Business, The Hong Kong Polytechnic University, Kowloon, Hong Kong. Tel: 852-34003457; Fax: 852-23309845; Email:aflei.yang@polyu.edu.hk. Tsai: Department of Applied Economics, National University of Kaohsiung, Taiwan. Tel: 886-7-5919189; Fax: 886-7-5919321; E-mail: yytsai@nuk.edu.tw. Mukherjee: Nottingham University Business School, UK. Tel: +44-(0)-1158467820; Fax: +44-(0)-1158466667; Email: arijit.mukherjee@nottingham.ac.uk.

JEL Classification Number(s): L13; L24; L40; H25; D43
Abbreviations: IPR
Number of Figures: 3
Number of Tables: 0
Date: May 13, 2015
Address of Contact Author: Yingyi Tsai, Department of Applied Economics, National University of Kaohsiung, Taiwan. Tel: 886-7-5919189; Fax: 886-7-5919321; E-mail: yytsai@nuk.edu.tw.

1. Introduction

Does patent reform attract better foreign technology? Assuming a higher imitation cost under a stronger patent system, Helpman (1993), among others, argues that a stronger patent system reduces technology flows from technologically efficient countries to technologically inefficient countries. Yang and Maskus (2001) show that stronger patent protection increases imitation costs but decreases technology transfer costs, yet the latter effect dominates, and a stronger patent protection attracts better technology. [1]

The aforementioned papers provide important insights, but ignore the strategic interactions among firms that often occur today. We show in an international duopoly setting that a stronger patent system's ability to attract better technology depends on the strength of two factors: (i) its effect on the technology transfer cost and (ii) the effect on knowledge spillover. A stronger patent system decreases (increases) quality of the technology to be transferred in the reforming country if its effect on knowledge spillover is stronger (weaker) than its effect on the technology transfer cost.

Our results are in contrast to Yang and Maskus (2009) showing that a stronger patent system attracts better technology by reducing the technology transfer cost. Although their result is intuitive, they ignored the knowledge spillover reducing effect of a stronger patent system. Our findings are also in contrast to the general equilibrium model of Yang and Maskus (2001) where the effect on the technology transfer cost dominates the knowledge spillover effect.

We further show that a stronger patent system decreases welfare of the reforming country if its negative effects on the quality of the transferred technology and reservation payoff of the domestic firms are stronger than its positive effect on the technology transfer cost. A stronger intellectual property right (IPR) may induce a foreign firm to shift from exporting to technology licensing, and may induce the reforming country to adopt a stronger IPR compared to the situation with no technology licensing. We also show the implications of different technology licensing contracts, viz., fixed-fee licensing contract and per-unit royalty licensing contract [2].

Our paper contributes to the extant literature on endogenous IPR protection. Žigić (1998) shows that the South (or developing country) may benefit and the North (the developed country) may be disadvantaged by a stronger IPR protection in the former. Žigić (2000) shows that tariffs can serve as a strategic trade policy for a Northern government to countervail weak Southern IPR protection. Cai and Li (2012) show that complete IPR protection may emerge in the presence of *quid pro quo* offered by the North in the North-South IPR negotiation. Tsai et al. (2004) show that intellectual property infringement need not always hamper an innovator's investment choices, and no cross-border IPR protection can be the mutually agreed level of protection in equilibrium. Naghavi and Tsai (2015) show the effect of bargaining between the North and the South on cross-border IPR. In a recent contribution, Marjit and Yang (forthcoming) identify two new channels through IPR affect innovations.

Our paper complements the aforementioned literature by focusing on the following factors. First, we show the Northern firm's endogenous choice of entry mode and quality of the transferred technology, which affects both the marginal cost of production and the technology transfer cost. Second, the IPR protection not only affects knowledge spillover under imitation but also the technology transfer cost under licensing. Third, we show the implications of both fixed-fee licensing and per-unit royalty licensing contracts.

The remainder of the paper is organized as follows. We describe our model and derive the results in Section 2. Section 3 compares the results obtained under fixed-fee licensing contract and per-unit royalty licensing contract. Section 4 concludes.

2. The Model and the results

Consider a world economy with two regions, North and South. Assume that at most one firm in each region can produce a homogeneous product. We denote these firms, which compete as Cournot duopolists, by firm N and firm S. The two markets are segmented, and the firms can charge different prices in each. Suppose that the inverse demand functions in the North and the South are given by $P_i = 1 - q_i$, where $i = N, S$; P is price and q is the total output.

Firm N innovated in an earlier period, and produces at zero marginal cost. Firm S, which does not innovate, produces at the marginal cost $c > 0$. Firm S benefits from firm N's technology through knowledge spillover, which may result from information disclosure in the patent application (Rockett, 1990; Zhang, 2012). The benefit of knowledge spillover to firm S depends on the Southern patent system. Assume that the "public goods" feature of firm N's patented technology allows firm S to produce at the marginal cost $c - m(k)$, where $m(k)$ represents firm S's benefit from knowledge spillover, a higher $k \in [0, 1]$ implies a stronger Southern patent system and $m'(k) < 0$.

Assume that in addition to exporting to the Southern market, firm N can license a technology to firm S. In the case of licensing, firm S is able to produce at a reduced marginal cost, depending on the quality of the technology transferred. Whether or not licensing occurs, firm S benefits from knowledge spillover $m(k)$. If x denotes the quality of the transferred technology, firm S's effective marginal cost under licensing is $c - m(k) - r(x)$, where $r(x)$ is the further cost reduction from licensed technology with $\frac{\partial r(x)}{\partial x} > 0$. Licensing involves a technology transfer cost, $F(x,k)$, which is borne by both firms. The better is the quality of the transferred technology, the higher is the transfer cost, with the increment decreasing with a stronger Southern patent system owing to the lower cost of contracting, i.e., $\frac{\partial^2 F(x,k)}{\partial x \partial k} < 0$ (Yang and Maskus, 2009).

We first consider a fixed-fee licensing scenario in which firm *N* charges an up-front fixed fee for the licensed technology. Note that licensing with a fixed-fee only captures empirical reality, as a large number of international technology licensing contracts are designed in this way (Vishwasrao, 2007). [3]

We consider the following game. At stage 1, the Southern government sets the Southern welfare maximising level of IPR. At stage 2, firm *N* decides whether to license its technology to firm *S*. If it decides to do so, it determines the quality of the transferred technology. The licensing fee is determined through a generalised Nash bargaining process. At stage 3, firms *N* and *S* compete like Cournot duopolists, and the profits are realized. We solve the game through backward induction.

We begin by analyzing the case in which licensing does not occur, and firm *S* imitates and produces at marginal cost $c - m(k)$. Solving for the Cournot-Nash equilibrium quantities, the equilibrium profits under no licensing are

$$\Pi_{NE}* = \frac{2[1 + c - m(k)]^2}{9}, \tag{1}$$

$$\Pi_{SE}* = \frac{2[1 - 2(c - m(k))]^2}{9}, \tag{2}$$

where $\Pi_{NE}*$ and $\Pi_{SE}*$ are the equilibrium profits of firms *N* and *S*, respectively. We assume that $\Pi_{SE}* = \frac{2[1-2(c-m(k))]^2}{9} > 0$, ensuring that imitation is the equilibrium strategy under no licensing.

To ensure that both firms always produce positive equilibrium outputs, we assume that $c < \frac{1}{2}$.

If licensing occurs at stage 1, the equilibrium profits of firms *N* and *S* are $\Pi_{NL} = \frac{2[1+c-m(k)-r(x)]^2}{9} + L$ and $\Pi_{SL} = \frac{2[1-2(c-m(k)-r(x))]^2}{9} - L$, respectively, where *L* represents the licensing fee.

The total net industry profit in the absence of licensing is $\Pi_E = \frac{2[1+c-m(k)]^2}{9} + \frac{2[1-2(c-m(k))]^2}{9}$, and that in the presence of licensing is $\Pi_L = \frac{2[1+c-m(k)-r(x)]^2}{9} + \frac{2[1-2(c-m(k)-r(x))]^2}{9} - F(x,k)$. Hence, the total joint gain from licensing is $(\Pi_L - \Pi_E) = S(x) - F(x,k)$, where $S(x) = \frac{2[1+c-m(k)-r(x)]^2}{9} + \frac{2[1-2(c-m(k)-r(x))]^2}{9} - \frac{2[1+c-m(k)]^2}{9} - \frac{2[1-2(c-m(k))]^2}{9}$.[4]

Let τ and 1-τ denote the bargaining powers of firms *N* and S respectively. If the firms bargain over the license fee, the reservation profit for firm *N* is its profit under exporting, $\Pi_{NE}*$, whereas the reservation profit for firm *S* is its profit under imitation, $\Pi_{SE}*$. The following maximization problem determines the non-negative licensing fee, L:

$$\underset{L}{Max} \left\{ \frac{2[1+c-m(k)-r(x)]^2}{9} + L - \Pi_{NE}* \right\}^{\tau} \left\{ \frac{2[1-2(c-m(k)-r(x))]^2}{9} - L - \Pi_{SE}* \right\}^{1-\tau}. \quad (3)$$

The equilibrium licensing fee is

$$L = \frac{2[1+c-m(k)]^2}{9} - \frac{2[1+c-m(k)-r(x)]^2}{9} + \tau[S(x)-F(x,k)], \quad (4)$$

and the equilibrium profits of the firms are $\prod_{NL} = \Pi_{NE}{}^{*} + \tau(\prod_L - \prod_E)$ and $\prod_{SL} = \Pi_{SE}{}^{*} + (1-\tau)(\prod_L - \prod_E)$.

Firm *N* determines the quality of the licensed technology by maximizing its total profit under licensing, i.e.,

$$\underset{x}{Max}\,\Pi_{NL} = \Pi_{NE}{}^{*} + \tau[S(x)-F(x,k)]. \quad (5)$$

The quality of the licensed technology should satisfy

$$[\frac{4}{9} - \frac{20}{9}(c-m(k)-r(x^*))]\frac{\partial r(x^*)}{dx} - \frac{\partial F(x^*,k)}{\partial x} \equiv f(x^*,k) = 0, \quad (6)$$

where x^* represents the equilibrium quality of the transferred technology. We assume that the second-order condition for maximisation is satisfied, i.e., $\frac{\partial f(x^*,k)}{\partial x} = [\frac{4}{9} - \frac{20}{9}(c-m(k)-r(x^*))]\frac{d^2 r(x^*)}{dx^2} + \frac{20}{9}[\frac{dr(x^*)}{dx}]^2 - \frac{\partial^2 F(x^*,k)}{\partial x^2} < 0$.

Differentiating (6) with respect to *k* and rearranging, we obtain

$$\frac{dx^*}{dk} = \frac{-\frac{20}{9}\frac{\partial m(k)}{\partial k}\frac{\partial r(x^*)}{\partial x} + \frac{\partial^2 F(x^*,k)}{\partial x \partial k}}{\frac{\partial f(x^*,k)}{\partial x}}. \quad (7)$$

Since $\frac{\partial f(x^*,k)}{\partial x} < 0$, we obtain $\frac{dx^*}{dk} > (<) 0$ for $-\frac{20}{9}\frac{\partial m(k)}{\partial k}\frac{\partial r(x^*)}{\partial x} + \frac{\partial^2 F(x^*,k)}{\partial x \partial k} < (>) 0$. At one extreme, if there is no knowledge spillover, as in Yang and Maskus (2009), we have *m(k) = 0* and $\frac{dx^*}{dk} > 0$, since $\frac{\partial^2 F(x,k)}{\partial x \partial k} < 0$. At the other extreme, if the Southern patent system does not affect the technology transfer cost, i.e., $\frac{\partial^2 F(x^*,k)}{\partial x \partial k} = 0$, we have $\frac{dx^*}{dk} < 0$, since $\frac{\partial m(k)}{\partial k} < 0$ and $\frac{\partial r(x^*)}{\partial x} > 0$, implying that $-\frac{20}{9}\frac{\partial m(k)}{\partial k}\frac{\partial r(x^*)}{\partial x} > 0$.

The effect of a stronger Southern patent system on the quality of the technology transferred is two-fold. On one hand, it tends to increase quality of the technology by reducing the transfer cost. On the other hand, it reduces knowledge spillover and widens the degree of technological difference between the firms, thus reducing firm *N*'s incentive to boost competition by transferring a relatively better technology. These effects are in line with the effects shown in Marjit (1990), albeit in a different context, suggesting that technology transfer does not occur under a fixed-fee licensing contract if the technological difference between the licensor and the licensee is large.

The following proposition summarizes the above discussion.

Proposition 1: *A stronger Southern patent system decreases (increases) quality of the licensed technology if that patent system's effect on knowledge spillover is stronger (weaker) than its effect on the technology transfer cost, i.e.,* $-\frac{20}{9}\frac{\partial m(k)}{\partial k}\frac{\partial r(x^*)}{\partial x} > (<) -\frac{\partial^2 F(x^*,k)}{\partial x \partial k}$.

Now we analyze how a stronger Southern patent system affects Southern welfare, which is the sum of Southern consumer surplus and firm *S*'s net profit. Let $q_{NL}{}^*$ and

$q_{SL}*$ (resp. $q_{NE}*$ and $q_{SE}*$) denote the total equilibrium outputs of firms *N* and *S* respectively, under licensing (resp. no licensing). Because we consider symmetric segmented markets and the same cost functions for production in both regions, the total equilibrium output of a firm is twice its equilibrium output in one market.

Southern welfare under licensing is

$$W_{SL} = G - (1-\tau)F(x^*, k), \tag{8}$$

since $\pi_{SE}* = 2*(\frac{q_{SE}*}{2})^2$, $S(x) = 2*(\frac{q_{NL}*}{2})^2 + 2*(\frac{q_{SL}*}{2})^2 - 2*(\frac{q_{NE}*}{2})^2 - 2*(\frac{q_{SE}*}{2})^2$

and

$$G = \frac{1}{2}[\frac{2-(c-m(k)-r(x^*))}{3}]^2 + \frac{2-(c-m(k))^2}{9} + \frac{2(1-\tau)}{9}\{5[2-(c-m(k)-r(x^*))]^2$$
$$-2[2-(c-m(k)-r(x^*))]-5[2-(c-m(k))]^2+2[2-(c-m(k))\}.$$

Differentiating W_s with respect to *k*, we obtain

$$\frac{dW_s}{dk} = \frac{\partial W_s}{\partial k} + \frac{\partial W_s}{\partial x}\frac{dx^*}{dk} = -(1-\tau)\frac{\partial F(x^*,k)}{\partial k} + \frac{\partial G}{\partial k} + \frac{\partial W_s}{\partial x}\frac{dx^*}{dk}. \tag{9}$$

We have $\frac{\partial F(x^*,k)}{\partial k} < 0$, implying that the first term on the right-hand side (RHS) of (9) is positive. It can be shown that $\frac{\partial G}{\partial k} < 0$, implying that the second term on the RHS of (9) is negative. If we adopt the usual assumption that industry profit increases as the marginal costs fall, we have $\frac{\partial S}{\partial x^*} > 0$.[5] Since $\frac{\partial (q_{NL}*+q_{SL}*)}{\partial x^*} > 0$ and $\frac{\partial S}{\partial x^*} > 0$, we have $\frac{\partial W_S}{\partial x} > 0$, implying that the third term is positive (negative) if $\frac{dx^*}{dk}$ >0 (<0).

Intuitively, a stronger Southern patent system exerts several conflicting effects on Southern welfare. First, it improves Southern welfare by reducing the technology transfer cost. Second, it diminishes it by reducing the reservation payoff of firm *S* under imitation. Third, it maximizes (minimizes) Southern welfare by lowering (raising) quality of the transferred technology.

To find out the closed-form solutions for optimal Southern IPR protection, we adopt the following specific functional forms: $m(k)=c(1-k)$, $r(x)=[c-m(k)]x$, $x\in[0,1]$ and $F(x,k)=ex(1-k)$, where $e>0$. Here, e is a constant. These explicit functional forms satisfy all of our previous assumptions.

To show how the possibility of licensing affects the optimal IPR protection, we first assume that firm *N* can choose exporting alone as its entry mode. In this case, the corresponding Southern welfare is

$$W_{SE}=\frac{1}{2}(\frac{q_{NE}*+q_{SE}*}{2})^2+\pi_{SE}*=\frac{(2-ck)^2+4(1-2ck)^2}{18}. \qquad (10)$$

Taking the derivative with respect to k, we get

$$\frac{dW_{SE}}{dk}=\frac{10c(2ck-1)}{9}. \qquad (11)$$

Thus, we have $\frac{dW_{SE}}{dk}<0$, since $c<\frac{1}{2}$. It follows that the optimal IPR protection under exporting is zero, and $W_{SE}*=\frac{4}{9}$. Therefore, the Southern government will choose the complete violation of IPR if licensing is not an option. This result is consistent with Cai and Li (2012) without *quid pro quo*.

If firm *N* chooses licensing as its entry mode, quality of the licensed technology should satisfy

$$[\frac{4}{9}-\frac{20}{9}ck(1-x^*)][c-m(k)]-e(1-k)=0. \quad (12)$$

The equilibrium quality of the licensed technology is $x^*=\frac{20c^2k^2-4ck+9e(1-k)}{20c^2k^2}$.

Southern welfare under licensing is derived by plugging the equilibrium quality of the licensed technology into the welfare expression (equation (8)), which gives:

$$\begin{aligned} W_{SL} &= G-(1-\tau)F(x^*,k)=\frac{1}{2}[\frac{12ck+3e(1-k)}{20ck}]^2+\frac{2(1-2ck)^2}{9} \\ &+\frac{2(1-\tau)}{9}\left\{5[\frac{36ck+9e(1-k)}{20ck}]^2-\frac{36ck+9e(1-k)}{10ck}-5(2-ck)^2+2(2-ck)\right\} \\ &-(1-\tau)\frac{e(1-k)[9e(1-k)+20c^2k^2-4ck]}{20c^2k^2}. \end{aligned} \quad (13)$$

Therefore, we obtain

$$\begin{aligned} \frac{dW_{SL}}{dk} &= \frac{4c^2k(5\tau-1)}{9}-\frac{e^2(171-180\tau)}{400c^2k^2}-\frac{9e(21-20\tau)}{100ck^2}+\frac{9e^2(19-20\tau)}{400c^2k^3} \\ &+\frac{4c(7-9\tau)}{9}+e(1-\tau). \end{aligned} \quad (14)$$

Let k_1 denote the Southern welfare maximizing IPR protection under licensing. Hence, k_1 satisfies

$$\frac{dW_{SL}}{dk}(k=k_1)=0. \quad (15)$$

We also have $\lim_{k\to 0}W_{SL}=\frac{4}{9}=W_{SE}$.

For $\varepsilon>0$ and $\varepsilon\to 0$, it follows from equation (14) that

$$\begin{aligned} \frac{dW_{SL}}{dk}(k=\varepsilon) &= \frac{4c^2\varepsilon(5\tau-1)}{9}+\frac{e}{400c\varepsilon^3}[\frac{9e(19-20\tau)-e\varepsilon(171-180\tau)}{c} \\ &-36\varepsilon(21-20\tau)]+\frac{4c(7-9\tau)}{9}+e(1-\tau). \end{aligned} \quad (16)$$

The first term in (16) is close to zero, whereas the second and third terms are positive for $\varepsilon > 0$ and $\varepsilon \to 0$ when τ is relatively small. As a result, $W_{SL}(k = \varepsilon) > W_{SE}$. It follows that $k_1 > 0$ if firm *S* enjoys a relatively strong bargaining position.

Let k_2 denotes the IPR protection level in the South when firm *N* is indifferent between licensing and exporting ($\Pi_{NL}(k_2) = \Pi_{NE}(k_2)$).[6] Let $k*$ denote the socially optimal IPR protection level in the South. Depending on the relationship between k_1 and k_2, the optimal IPR protection in the South can be summarized into three possible cases. Figure 1 shows the situation of k_2 being less than k_1, in which case the Southern government sets $k* = k_1$, since by doing so, it creates the maximum possible Southern welfare under licensing and induces firm *N* to undertake licensing.

We next consider the scenario where k_2 is greater than k_1, and the Southern welfare is better under licensing than under exporting at k_2, [7] which is shown in Figure 2. In this case, $k* = k_2$.

The final scenario, which is depicted in Figure 3, is when k_2 is greater than k_1, and the Southern welfare is worse under licensing than under exporting at k_2. In this scenario, even if a stronger IPR protection could attract licensing, the South would prefer not to, opting instead to generate maximum Southern welfare under exporting by choosing $k* = 0$.

INSERT Figure 1 here.

INSERT Figure 2 here.

INSERT Figure 3 here.

From equation (14) we have

W_{SL}

$$\frac{dW_{SL}}{dk}(\tau=1)=\frac{8c(2ck-1)}{9}+\frac{9e^2(k-1)}{400c^2k^3}-\frac{9e}{100ck^2}-\frac{8c}{9} \quad . \tag{17}$$

Since $c<\frac{1}{2}$ and $k\leq 1$, it can be shown that $\frac{dW_{SL}}{dk}(\tau=1)<0$. Since $\frac{dW_{SL}}{dk}$ is continuous in τ, it follows that $\frac{dW_{SL}}{dk}<0$ for τ close to 1. Therefore the optimal IPR under licensing is zero if firm S has a relatively weak bargaining position, which is the same as that of under exporting.

The above discussion is summarized in the following proposition.

Proposition 2. *The optimal IPR protection level under a fixed-fee licensing contract could be higher than that of under exporting when firm* S *enjoys a relatively stronger bargaining position. The possibility of licensing increases the incentive for a stronger IPR protection in the South, unless Southern welfare under licensing at the IPR strength required attracting licensing is worse than that of under exporting. Otherwise, it is the same as that of under exporting.*

If a stronger Southern IPR induces licensing, it creates the following effects. First, a stronger Southern IPR tends to reduce firm S's profit by reducing it reservation payoff under licensing. Second, if firm S's bargaining power is high, it tends to increase firm S's profit under licensing by allowing it to extract a larger share of the surplus generated through licensing. Third, a stronger Southern IPR tends to increase consumer surplus by inducing licensing. Unless the IPR strength that needs to induce licensing is very high, the last two effects dominate the first effect and the optimal IPR under licensing is higher than that of under export.

3. Royalty Licensing

In this section, we consider a per-unit royalty licensing contract to capture the feature that some technology licensing contracts extract per-unit royalties.[8] In this scenario, the licensing contract specifies a per-unit output royalty (*l*).

If firm *N* licenses a technology of quality *x*, the total outputs in the North and South are $q_{NT} = 2\frac{1+c-m(k)-r(x)+l}{3}$ and $q_{ST} = 2\frac{1-2[c-m(k)-r(x)+l]}{3}$ respectively.

Therefore, the net profits of firms *N* and *S* are given by

$$\prod_{NT} = \frac{2[1+c-m(k)-r(x)+l]^2}{9} + 2l\frac{1-2[c-m(k)-r(x)+l]}{3} - F(x,k), \quad (18)$$

$$\prod_{ST} = \frac{2[1-2(c-m(k)-r(x)+l)]^2}{9} - 2l\frac{1-2[c-m(k)-r(x)+l]}{3}, \quad (19)$$

where $\prod_{NT}$ and $\prod_{ST}$ refer to the profits of firms *N* and *S* respectively under the royalty licensing contract.

Equilibrium *l* is determined by maximizing the following expression.

$$\underset{l}{Max}(\prod_{NT} - \prod_{NE}{}^*)^{\tau}(\prod_{ST} - \prod_{SE}{}^*)^{1-\tau}, \quad (20)$$

where $\prod_{NT}$ and $\prod_{ST}$ are the payoffs of firms *N* and *S* under licensing, and $\prod_{NE}{}^*$ and $\prod_{SE}{}^*$ are their respective reservation payoffs. The joint surplus of the two parties under a per-unit output royalty licensing contract is $\prod_{NT} + \prod_{ST} - (\prod_{NE}{}^* + \prod_{SE}{}^*)$. Taking into account the constraints of $l \geq 0$ and $l \leq r(x)$, it can be verified that $l = r(x)$ in equilibrium. This result is consistent with that of in Rockett (1990). The licensee will be held to the same effective cost level as it had under no licensing because it has no alternative other than to accept or reject the license and remains at its original cost level.

Firm N chooses the quality of the licensed technology to solve

$$\underset{x}{Max}\,\Pi_{NL} = \frac{2[1+c-m(k)]^2}{9} + 2r(x)\frac{1-2[c-m(k)]}{3} - F(x,k)\,. \tag{21}$$

The equilibrium quality of the licensed technology satisfies

$$[\frac{4}{9} - \frac{20}{9}(c-m(k)]\frac{\partial r(x^{**})}{dx} - \frac{\partial F(x^{**},k)}{\partial x} \geq 0\,, \tag{22}$$

where x^{**} represents the quality under a per-unit royalty licensing contract.

Using the functional forms specified in Section 3, we find the marginal benefit and the cost of technology transfer to be $(\frac{4}{9} - \frac{20}{9}ck)ck$ and $e(1-k)$, respectively. Therefore, $x^{**}=1$ if $(\frac{4}{9} - \frac{20}{9}ck)ck > e(1-k)$ and $x^{**}=0$ if $(\frac{4}{9} - \frac{20}{9}ck)ck < e(1-k)$.

Let k^{**} denote the optimal Southern IPR protection under a per-unit royalty licensing contract. If the Southern government anticipates that $x^{**} = 0$ ex-post IPR determination, it will choose $k^{**} = 0$. Accordingly, Southern welfare is the same as it would be under exporting. If the Southern government instead anticipates that x** = 1 ex-post the IPR determination, the Southern welfare is

$$W_{ST} = \frac{1}{2}(\frac{q^*_{NT} + q^*_{ST}}{2})^2 + \pi^*_{SE} = \frac{(2-ck)^2 + 4(1-2ck)^2}{18}\,. \tag{23}$$

It then follows from (11) that the Southern government will again choose $k^{**}=0$ and we get $x^{**}=0$. Hence, we have the following proposition.

Proposition 3. *The optimal IPR protection in the South under a per-unit royalty licensing contract is the same as that of under export, and may be weaker than that of under a fixed-fee licensing contract. The equilibrium quality of the licensed technology under a per-unit royalty licensing contract is inferior than that of under a fixed-fee licensing contract.*

The optimal IPR is the same under a per-unit royalty licensing and export since the royalty rate cancels the quality effect. The above result also shows that quality of the transferred technology and optimal IPR depends on the type of licensing contract.

4. Conclusion

We show the effects of a stronger patent system in developing countries on the quality of licensed technology and welfare. We show that a stronger patent system can reduce both the quality of the licensed technology and welfare. The effect of the patent system on knowledge spillover relative to the technology transfer cost plays important role for our results. Thus, our results provide new insights to the literature on IPR protection and technology licensing in the broader context of development.

References

An, Galina, Keith Maskus and Thitima Puttitanun, "Duration of Rent Extraction and the Entry Mode Decision of Multinational Enterprises," *Review of Development Economics* 12 (2008): 861-76.

Cai, Dapeng and Jie Li, "Quid pro quo and the enforcement of intellectual property rights protection: A bargaining approach," *The Journal of International Trade & Economic Development* 21 (2012): 755–72.

Helpman, Elhana, "Innovation, imitation, and intellectual property rights," *Econometrica* 61 (1993): 1247–80.

Marjit, Sugata, "On a non-cooperative theory of technology transfer," *Economics Letters* 33 (1990): 293-98.

Marjit, Sugata and Lei Yang, "Intellectual Property Right and R&D when Pirates are Innovators", *International Review of Economics and Finance*, forthcoming.

Naghavi, Alireza and Yingyi Tsai, "Cross-border intellectual property rights: contract enforcement and absorptive capacity," *Scottish Journal of Political Economy* 62 (2015): 211- 26.

Rockett, Katharine, 1990, "The quality of licensed technology," *International Journal of Industrial Organization* 8: 559-574.

Rostoker, Michael D., A survey of corporate licensing, *IDEA 24* (1984), 59–92.

Tsai, Yingyi, Luka Brkic, and Edward McPhail, “Negotiations over Intellectual Property Protection: A Strategic Bargaining Aspect,” *Zagreb International Review of Economics and Business* 7 (2004), 1-25.

Vishwasrao, Sharmila, “Royalties versus fees: how do firms pay for foreign technology? ” *International Journal of Industrial Organization* 25 (2007): 741–59.

Yang, Guifang and Keith Maskus, “Intellectual property rights, licensing, and innovation in an endogenous product-cycle model,” *Journal of International Economics*, 53 (2001): 169-87.

Yang, Lei and Keith Maskus, “Intellectual property rights, technology transfer and exports in developing countries,” *Journal of Development Economics* 90 (2009): 231-236.

Zhang, Tianle, “Patenting in the shadow of independent discoveries by rivals,” *International Journal of Industrial Organization* 30 (2012): 41-49.

Žigić, Krešimir, “Intellectual property rights violations and spillovers in North-South trade,” *European Economic Review* 42 (1998): 1779-1799.

Žigić, Krešimir ,“Strategic trade policy, intellectual property rights protection, and North–South trade’, *Journal of Development Economics* 61 (2000): 27–60.

Notes

1. See An et al. (2008) for an empirical analysis of this subject.

2.Technology licensing contracts differ significantly in reality (Rostoker, 1984). Fixed-fee licensing and royalty licensing have been used widely in the technology licensing literature. As mentioned below, the results under the royalty licensing holds also for a two-part tariff licensing contract.

3. In India, between 1991 and 1993, 968 international licensing contracts in the manufacturing sector, i.e., 45% of all licensing deals in the sector, were fixed fee-only contracts (Vishwasrao, 2007).

4. Licensing is profitable only if $[S(x)+I(k,a)-F(x,k)]>0$, which we assume to hold.

5. Let c_1 and $c_2(>c_1)$ denote the marginal costs of Firms 1 and 2. It follows from Marjit (1990) that the Cournot industry profit increases as c_2 falls if $c_2 < \frac{a+4c_1}{5}$.

6. We assume that the condition for $\pi_{NL} > \pi_{NE}$, $-\frac{10}{9}c^2k^2+(4c+e)k-\frac{9e}{5c}-\frac{34}{45}-\frac{9e^2}{40c^2}-e+\frac{9e^2+36ec}{20c^2k}-\frac{9e^2}{40c^2k^2}>0$, is satisfied for $k>k_2$.

7. Southern welfare under licensing is greater (less) than that under exporting when $\frac{9}{50}+\frac{2(1-\tau)}{45}[63-25(2-c)^2+10(2-c)]>(<)\frac{(2-c)^2}{18}$.

8. Our analysis can be extended to the two-part tariff licensing scenario. The equilibrium values under a two-part tariff licensing contracts are the same as those under a per-unit royalty licensing contract.

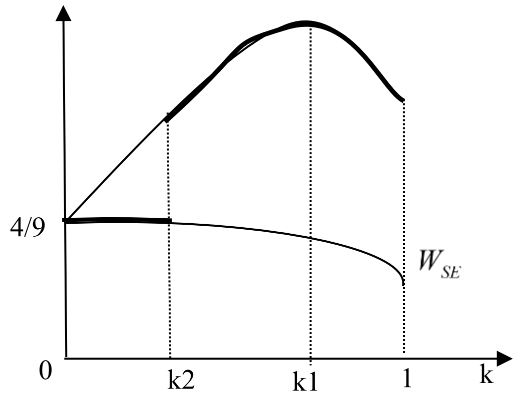

Figure 1 Optimal IPR protection when $k_2 < k_1$

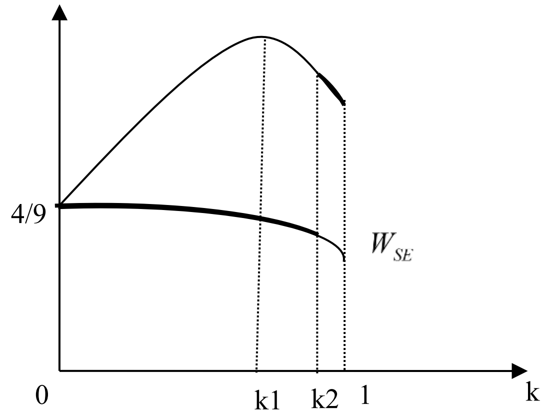

Figure 2 Optimal IPR protection when $k_2 > k_1$ and $W_{SL} > W_{SE}$ at k_2

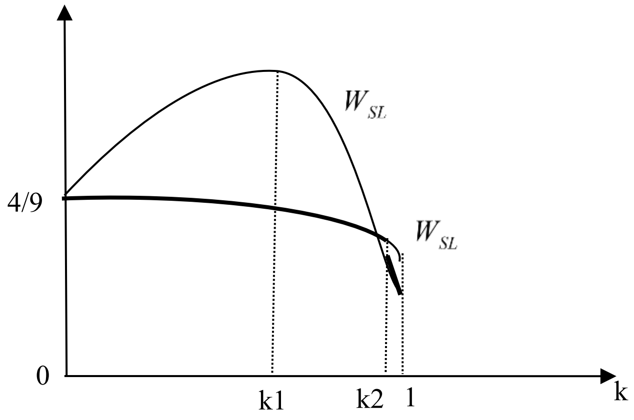

Figure 3 Optimal IPR protection when $k_2 > k_1$ and $W_{SL} < W_{SE}$ at k_2