Forthcoming in *Journal of Economics*

Domestic Patenting Systems and Foreign Licensing Choices

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Accepted: January 17, 2017

Abstract. This paper examines a foreign technology holder's licensing choices between royalty and fixed-fee scheme. We emphasize that foreign licensor chooses the quality of licensed technology when the licensee country does not implement perfect intellectual property protection for licensor's technology. We study quality choice as the foreign licensor's selection for a particular grade of technical skills. We show that fixed fee emerges as the equilibrium licensing scheme when both the transfer of his technology is relatively efficient and the licensee is sufficiently cost competitive in the domestic market, and that royalty licensing prevails otherwise. We further show it need not hold the general belief that welfare in the licensor country unambiguously rise with a stronger patenting system in the licensee country when, in particular, such patenting system in place is sufficiently lax.

Key Words: Intellectual Property Protection; Licensing; Quality of the licensed technology; Welfare

JEL Classification: L13; L24; L40; H25; D43

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Domestic Patenting Systems and Foreign Licensing Choices

1. Introduction

A patent allows the inventor for a certain period of time during which he is entitled to manage the diffusion of his invention. Patenting, therefore, serves as an incentive for innovation when, in particular, the inventor can reap the fruit of his investment in *R&D*. Generally, the innovator can realize a profit on the research outcome either from his filing for the patent or through the licensing of the patent. In the case of patent licensing, the most frequently observed types of contract include fixed fee, per unit royalty and/or a combination of fixed fee and royalties (see, for example, San Martin and Saracho, 2010; Vishwasrao, 2007).

As a major seller of technology, the United States accounts for roughly 50% of world revenue of royalty and license fee (World Development Indicators, 2010). The multinational corporations (MNC) with US origin have been the key channels of transfer for technical know-how, industrial processes and computer software. Empirical evidence has shown that two-thirds of royalties and license receipts come from intra-firm transactions and approximately 60% of total trade within U.S. multinationals trade in intermediate inputs (The U.S. Bureau of Economic Analysis, 2004).

It is often believed that a weaker patenting[1] regime in the domestic country is harmful for the business interests of foreign innovative licensor. This occurs due to knowledge spillovers that increase domestic competition, reduce price and raise welfare of the licensee country. Despite this theoretical underpinning, domestic imitation in some developing countries is often acquiesced so long as it does not discourage foreign innovation. In the light of substantial business losses of US

[1] In this paper, the terms of "patenting" and "intellectual property protection" are used interchangeably.

multinationals due to inadequate protection of *IPR*s abroad, the United States Trade Representative (USTR) amended in 1994 the Special 301 provisions of the Trade Act of 1974.[2] Special 301 was regarded as a success after Brazil had agreed to the immediate implementation of the TRIPS provisions without resorting to the transition period permitted to the developing nations (Doane, 1994).

This paper examines a foreign inventor's choices of two licensing schemes – per unit royalty and fixed fee. In particular, the foreign licensor decides the quality of licensed technology when the domestic country does not implement perfect intellectual property protection for foreign technology.[3] In the present context of licensing, the domestic licensee acquires foreign technology in terms of its level of technological advancement. The closer the licensed technology level approximates its "state-of-the-art" (or the frontier) one, the better the quality. We study quality choice as the foreign licensor's selection for a particular grade of technical skills. We show, for both a weak and a strong patenting system in the domestic country, that a foreign licensor, under the fixed fee scheme, always transfer the "state-of-the-art" technology to the domestic licensee when the efficiency of such transfer is sufficiently high. We further show that fixed fee emerges as the equilibrium licensing scheme when both the transfer of his technology is relatively efficient and the licensee is sufficiently cost competitive in the domestic market, and that royalty licensing prevails otherwise. We also investigate the welfare implications of domestic patenting system for the foreign innovator's licensing policy. And we show that welfare in the licensor country need not unambiguously rise with a stronger patenting system in the licensee country when,

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[2] This requires USTR to identify as the "priority watch list" foreign countries that deny adequate and effective protection of *IPR*s, or fair and equitable market access for U.S. persons that rely on IP protection. Indeed, The USTR has requested and received submissions from U.S. industries suggesting that several nations be included on priority, priority watch, and watch lists. These submissions include many of the nations, which opposed the TRIPS negotiations and putting it into force, such as India and Brazil.

[3] See Kabiraj and Marjit (1993), Maskus (1998), Yang and Maskus (2001) and Amir et al. (2011) for the impacts on licensing schemes under weak and strong patent system, respectively.

in particular, such patenting system in place is sufficiently lax.

The novelty of our paper is that domestic patenting system impacts on the foreign inventor's licensing decisions through endogenous quality choice.[4] We argue, in addition to the strategic effects on host market competition, that there exist trade-offs while deciding the licensing modes. We investigate the role that per unit royalty[5] plays, in particular, under weak domestic patenting regime in facilitating the endogenous choice of an exact quality level of foreign licensed technology (cf. Vishwasrao, 2007; Amir et al., 2011; Colombo and Filippini, 2016). This paper, however, is not the first to explore the quality of licensed technology in a licensing agreement. This formulation is closest to Rockett (1990) who considers that a licensor can choose from his patent a particular vintage of the technological profile and the structure of payment (i.e., licensing scheme).

This paper differs from previous works in three aspects. First, our paper marks a subtle distinction between the quality choice of technology and process innovation.[6] Process innovation does not involve a payment from the competing firms. And if it is subsequently used for production, e.g., in a cost reduction manner, by the licensee, the quality being transferred from the licensor captures specifically the impact on the extent to which the licensee's cost is reduced. Our handling of this issue departs from the general setup in which the nature of licensed technology is a cost-reducing one".[7] Second, this model links directly the quality of licensed technology to the efficiency-adjusted technology transfer cost that is borne by the licensor, while Rockett (1990)

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[4] Mukherjee and Tsai (2015) consider optimal quality choice of licensed technology under perfect patenting. And Amir et al. (2011) examine licensing schemes in a weak patent system when a patent might be invalidated if challenged in court.

[5] In an interesting contribution, Colombo and Filippini (2016) study different licensing schemes and compare two-part tariff to both schemes of ad valorem royalty contracts and revenue-royalty contracts, where the price, rather than the quantity, is the basis of the licensing contract.

[6] The authors thank an anonymous referee for suggesting a clarification on the linkage between quality choice and cost-reducing technology.

[7] See, for example, Wang (1998), Sinha (2010), and San Martin and Saracho (2010). These papers consider merely the transfer of cost-reducing technology in licensing contract without exploring the role that quality choice plays in affecting the mode of technology licensing.

approximates "costly transfer" to the extreme case of "no imitation" of technology, Mukherjee and Tsai (2015) consider costly transfer which involves both a fixed and an adjustment cost in transferring technology, and Yang et al. (2016) examines optimal licensing schemes under Nash bargaining setting without integral linkages of technology quality to the cost of its transfer. And third, the present model considers that the patenting system in the licensee country is exogenously given and directly affects in a multiplicative manner the licensee's marginal cost *ex post* licensing, while Yang et al. (2016, pp. 240-241) consider endogenous domestic *IPR*s regime in the licensee country and separate, in an additive manner, the spillovers effect (which arises from the different strengths of *IPR*s in the licensee country) from the quality effect (which holds when different grades of foreign technology directly affect the licensee's cost).

The rest of this paper is organized as follows. Section 2 describes the basic model. Section 3 discusses the main results and their implications. And Section 4 concludes.

2. The basic model

We consider a world economy with two countries, foreign and domestic. Each country has one firm, denoted by 1 and 2, respectively. Assume that firm 1 is foreign and firm 2 domestic. In the domestic market, the two firms compete *a la* Cournot with a homogeneous product. Firm 1 holds patents for its technology profile that is captured by a range of marginal cost over [0, c]. Nonetheless, firm 1 can choose any level of quality, s, from the technology set [0, c] and license to firm 2. Hence, firm 1 determines both quality of the licensed technology and the payment structure. For analytical simplicity, we shall consider that firm 1 uses the "state-of-the-art" (or the frontier) technology and produces at zero marginal cost, while firm 2 produces at some positive marginal cost of c prior to licensing.

We consider two types of domestic patenting regime, namely, weak patenting (*WP* henceforth) and strong patenting (*SP* henceforth). Under *WP*, imitation (or reverse engineering) allows for spillovers to the domestic firm of the foreign technical know-how. Hence, for any weak domestic patenting system, the marginal cost of firm 2 is αc, where $\alpha \in (0,1]$ captures the strength of patenting system in the licensee country. The greater the value of α, the stronger the domestic *IPR*s system. In the extreme of a strong patent protection (*SP*), the marginal cost of domestic firm 2 is given by c and, thus, imitation does not take place (that is, $\alpha = 1$). We assume, in the case of imitation, that the licensor (firm 1) cannot collect royalty for the licensee's (firm 2's) production. This key feature of our model reflects that both fixed-fee (*F*) and per unit royalty (*R*) licensing are available under *SP* in the domestic country, that only the fixed fee licensing (*F*) is feasible under *WP* in the licensee country[8] and that a two-part tariff licensing collapses into a fixed-fee one under *WP*.

In order to highlight the impact of the patenting regime in the licensee country on the foreign firm's licensing policy, we study the licensing schemes of fixed-fee (*F*) and royalty (*R*) under both *WP* and *SP*, respectively. We investigate the subgame perfect equilibrium (*SPE*) outcome of licensing contract (*F vs*. *R*) and the quality of licensed technology under each licensing scheme (s^F and s^R). And we summarize the licensing game with different *IPR*s strengths in the licensee country as follows. First, foreign licensor decides the quality of licensed technology *s*. Given the quality choice of licensed technology, foreign firm 1 then sets the licensing payment structure by a take-it-or-leave-it offer of licensing contract, domestic licensee accepts if it is not worse off than no licensing, and rejects otherwise. Finally, the two firms engage in

[8] Put differently, a weak domestic patenting implies the licensee's output *ex post* licensing is not observable and, thus, royalty licensing is not feasible under *WP*.

Cournot competition by setting quantity in the domestic markets. The payoffs to the two firms are their profits. The inverse demand function is given by $P = 1 - q$, where P is price and q is the total output sold. We solve the game through the method of backward induction.

Clearly, foreign firm 1 first selects the quality of its licensed technology s, where $s \in [0, \alpha c]$ under *WP* and $s \in [0, c]$ under *SP*. Higher s suggests a better quality of technology being transferred and, thus, implies a lower marginal cost of firm 2 *ex post* licensing. In the extreme of $s = 0$, firm 1 does not license any of its technology since reduction of marginal cost does not occur under either *WP* or *SP*. Further, when firm 1 transfers the best of its technology, we have $s = \alpha c$ under *WP* and $s = c$ under *SP*. We consider that technology transfer involves a total cost $C(s) = \gamma s^2 / 2$, where γ is an inverse measurement of transfer efficiency for a particular quality of the licensed technology. Since the licensor solely incurs such cost, a higher γ reflects a lower level of efficiency in transferring technology and vice versa when the transfer efficiency is interpreted as the licensee's capacity in absorbing outside knowledge or the legal restraints in either country of the licensor or the licensee. Real world observation[9] suggests that there are costs involved in setting enforceable contact terms and shifting codified knowledge when, in particular, the licensed technologies require further modification in accordance with the licensee's technological capacity.

2.1. Benchmark

Before studying the firm's interactions under licensing, we first consider the profits of the firms under no licensing. This allows us to establish the reservation payoffs as the benchmark for the licensing contract.

[9] It is well documented that technology licensing requires significant amount of transaction costs (Teece, 1976; Taylor, 1993; Yang and Maskus, 2009).

Under no licensing, the marginal costs of firms 1 and 2 are, respectively, 0 and αc under *WP*, and 0 and *c* under *SP* since $\alpha = 1$. Hence, the profit of firm 1 and firm 2 is, respectively, given by

$$\pi_1^{NL} = \begin{cases} \dfrac{(1+\alpha c)^2}{9}, \textit{ if } WP \\ \dfrac{(1+c)^2}{9}, \textit{ if } SP \end{cases} \quad \text{and} \quad \pi_2^{NL} = \begin{cases} \dfrac{(1-2\alpha c)^2}{9}, \textit{ if } WP \\ \dfrac{(1-2c)^2}{9}, \textit{ if } SP \end{cases}. \tag{1}$$

To ensure interior solution of the licensing game, we restrict our analysis to $c < 1/2$ for any $\alpha \in (0,1]$ so that the firms always produce positive outputs.

2.2 Fixed-fee licensing under WP and SP

We first consider the case of a fixed-fee licensing. Under *WP*, for any technology of quality $s \in [0, \alpha c]$, competition in the output stage gives, respectively, the equilibrium profit of firm 1 and firm 2 as

$$\pi_1^F = \frac{(1+\alpha c - s)^2}{9} + F, \tag{2}$$

$$\pi_2^F = \frac{(1-2\alpha c + 2s)^2}{9} - F, \tag{3}$$

where *F* is the fixed-fee charged by firm 1.[10]

Clearly, the licensee (firm 2) accepts the licensing contract provided that the equilibrium fixed-fee being charged leaves non-negative rent for participation, i.e.,

$$F^* = \frac{(1-2\alpha c + 2s)^2 - (1-2\alpha c)^2}{9}. \tag{4}$$

Following backward induction, the licensor (firm 1) chooses $s \in [0, \alpha c]$ in the first stage, subject to Equation (4), and solves for

$$\max_{s \geq 0} \pi_1^F = \frac{\overbrace{(1+\alpha c - s)^2}^{\textit{licensor's revenue}} + \overbrace{(1-2\alpha c + 2s)^2 - (1-2\alpha c)^2}^{\textit{fixed-fee licensing revenue}}}{9} - \frac{\gamma s^2}{2}. \tag{5}$$

[10] In the output stage, the cost of transferring technology is sunk and, thus, has no effect on the equilibrium fixed licensing fee.

The *SPE* outcome of quality for the licensor's technology under fixed-fee licensing is

$$s^F = \frac{2-10\alpha c}{9\gamma-10}, \tag{6}$$

where the denominator $9\gamma-10>0$ is obtained from the second-order condition. This condition ensures that Equation (5) is concave in *s*, which allows us to bring out the main message and analytical simplicity in the present analysis.[11]

Proposition 1 summarizes foreign firm's licensing decision under fixed-fee licensing in the presence of weak patenting system in the licensee country.

Proposition 1: *Given a weak patenting* (*WP*) *system in the licensee country,* i.e., $\alpha \in (0,1]$, *foreign licensor* (*firm 1*)

(a) conducts fixed-fee licensing when either the licensee is not sufficiently cost competitive (i.e., $c > 1/5\alpha$) *or the domestic patenting regime in place is already sufficiently strong* (i.e., $\alpha > 1/5c$); *and*

(b) transfers (*i*) *the "state-of-the-art"* (i.e., *the frontier*) *quality of technology* $s_W^F \equiv \alpha c$ *for any sufficiently high efficiency of technology transfer* (*i.e.,* $\frac{10}{9} < \gamma \le \frac{2}{9\alpha c}$); *but* (*ii*) *not the best quality level of* $s_W^F \equiv \frac{2(1-5\alpha c)}{(9\gamma-10)} < \alpha c$ *for any sufficient low technology transfer efficiency* (i.e., $\frac{10}{9} < \frac{2}{9\alpha c} < \gamma$).

Under fixed fee licensing and given the intermediate technology transfer efficiency ($\gamma > 10/9$), Equation (6) implies that foreign licensor's decision rests upon the trade-off between the licensee's cost competitiveness (*c*) and the strength of domestic patenting system ($\alpha \in (0,1]$).[12] Intuitively, the strength of domestic *IPR*s system ($\alpha < 1$) impacts on the licensor's cost advantage against that of the licensee and, therefore, the rent accrued to the licensor under fixed-fee licensing. For any

[11] Elsewhere, we explicit investigate the case of $9\gamma-10<0$ and show that the licensor's profit is convex in its choice of technology quality (see the discussion in Mukherjee and Tsai (2015, p. 68)).

[12] For any $\alpha \in (0,1]$ and $\gamma > 10/9$, it is easy to verify that $s^F = \frac{2-10\alpha c}{9\gamma-10} < \alpha c$ holds for any $\alpha c < \frac{1}{5}$ and $\gamma > \frac{2}{9\alpha c}$, i.e., $\frac{2}{9\gamma c} < \alpha < \frac{1}{5c}$; and that $s^F = \alpha c$ holds for any $\frac{10}{9} < \gamma < \frac{2}{9\alpha c}$ and $\alpha c < \frac{1}{5}$, implying that $\alpha c < \min\{\frac{2}{9\gamma}, \frac{1}{5}\} = \frac{1}{5}$ and $\gamma \le \frac{2}{9\alpha c}$.

selected quality of the licensed technology, foreign licensor alone incurs total cost of technology transfer and such cost moves inversely with the technology transfer efficiency (γ). If γ reflects the degree of convexity associated with the licensor's total technology transfer cost, then a lower γ is equivalent to a higher technology transfer efficiency. Proposition 1 and Corollary 1 provides the background for sketching Table 1 and Figure 1 with the relevant parameter values of technology transfer efficiency (γ), the cost competitiveness between the licensor and the licensee (c) under a weak domestic patenting system $(\alpha < 1/5c)$.[13]

We sketch, in Table 1, the equilibrium quality of licensed technology (s_W^F) subject to the interactions among γ, c and α, where $\alpha < 1/5c$.

Table 1. $s_W^F < \alpha c$, $\gamma > 10/9$ and $\frac{2}{9\gamma} < \alpha c < \frac{1}{5}$

s_W^F	γ		$s_W^F < \alpha c$				
		α	c	α	c	α	c
0.131	1.45	0.3	0.53	0.5	0.32	0.7	0.22
0.098	1.45	0.3	0.56	0.5	0.34	0.7	0.24
0.065	1.45	0.3	0.6	0.5	0.36	0.7	0.25
0.052	1.95	0.3	0.53	0.5	0.32	0.7	0.22
0.039	1.95	0.3	0.56	0.5	0.34	0.7	0.24
0.026	1.95	0.3	0.6	0.5	0.36	0.7	0.25
0.042	2.15	0.3	0.53	0.5	0.32	0.7	0.22
0.032	2.15	0.3	0.56	0.5	0.34	0.7	0.24
0.021	2.15	0.3	0.6	0.5	0.36	0.7	0.25

Figure 1 illustrates, based upon Table 1, the *SPE* outcome of equilibrium quality of the licensed technology under fixed fee in the presence of weak domestic patenting. Notice that the equilibrium quality of licensed technology s_W^F falls with a greater value of γ, where γ is an arbitrary number satisfying $\gamma > 10/9$ and $\gamma = 1.45$ $\gamma' = 1.95$ and $\gamma'' = 2.15$.

[13] The authors thank an anonymous referee for suggesting a graphical presentation with numerical example for better presentation of the results.

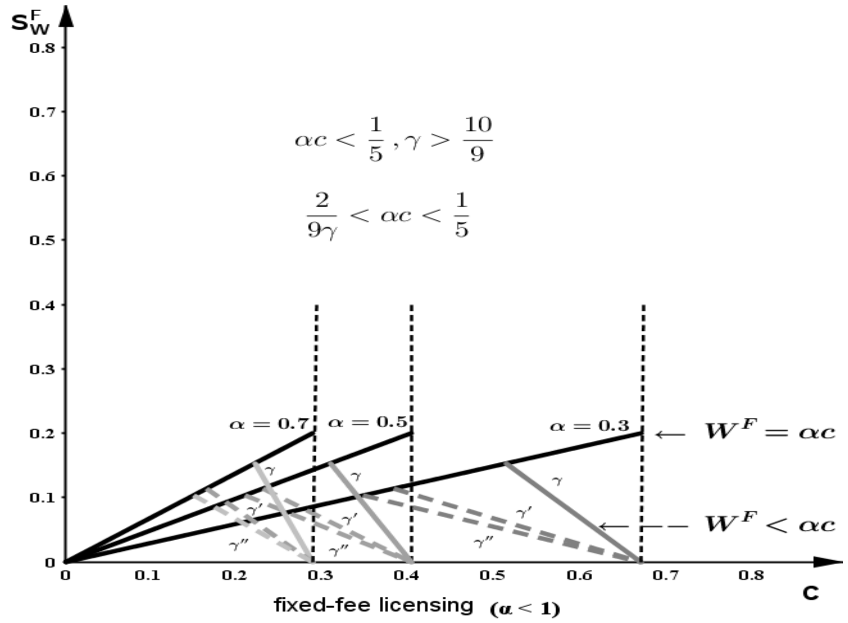

Figure 1 *Weak Patenting* ($\alpha < 1$) with $\gamma = 1.45$, $\gamma' = 1.95$ and $\gamma'' = 2.15$

With strong patenting system (*SP*) in the licensee country (i.e., $\alpha = 1$), we summarize in Corollary 1 the equilibrium scheme of fixed-fee licensing.

Corollary 1: *Given a strong patenting* (*SP*) *in the licensee country, i.e.,* $\alpha = 1$, *foreign licensor* (*firm 1*)

(a) *conducts a fixed-fee scheme only if the licensee produces at sufficiently low marginal cost*, i.e., $c < 1/5$; and

(b) *transfers (i) the "state-of-the-art"* (*or the best*) *quality of technology* $s_F^F = c$ *if the efficiency of technology transfer is sufficiently high* (*i.e.,* $\frac{10}{9} < \gamma \leq \frac{2}{9c}$)*; but (ii) not the highest quality level of* $s_F^F \equiv \frac{2(1-5c)}{9\gamma - 10} < c$ *for any sufficiently low transfer efficiency* (i.e., $\frac{2}{9c} < \gamma < \frac{1}{5}$).

Proof. For similar derivation, see Mukherjee and Tsai (2015, pp. 67-8).

Table 2 summarizes the equilibrium quality of licensed technology (s_S^F) contained in Corollary 1 under strong patenting ($\alpha = 1$) for any technology transfer efficiency (γ), the cost competitiveness between the licensor and the licensee (c).

Table 2. $s_S^F < c$, $\gamma > 10/9$, $\alpha = 1$ and $\frac{2}{9\gamma} < c < \frac{1}{5}$

s_S^F	γ	$s_S^F < \alpha c$ (α=1)
		c
0.16	1.25	0.18
0.12	1.25	0.185
0.08	1.25	0.19
0.05	1.55	0.18
0.037	1.55	0.185
0.025	1.55	0.19
0.026	1.95	0.18
0.019	1.95	0.185
0.013	1.95	0.19

Figure 2 illustrates the intuitive explanation of this result, which follows through the same argument, except that $\alpha = 1$ here, as stated in that for Proposition 1.

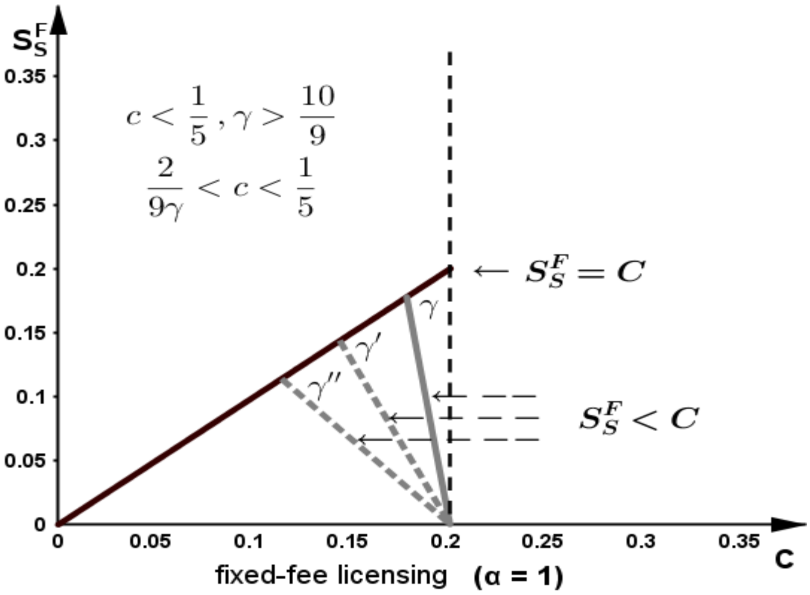

Figure 2 *Strong Patenting* ($\alpha = 1$) with $\gamma = 1.25$, $\gamma' = 1.55$ and $\gamma'' = 1.95$

It is worth highlighting that the nature of technology transfer and the context to which it is applied have important implications. Comparing technology transfer in the present model to that in Colombo and Filippini (2016), we note the following differences: foreign licensor solely incurs the cost of technology transfer, which is an efficiency-adjusted (quadratic) function of technology quality (*s*), while technology transfer in Colombo and Filippini (2016) relates directly with total output (p. 50). In line with the interpretation of γ in the present model, if we interpret the technology parameter *k* in Colombo and Filippini (2016, pp. 50, 66) as an inverse measurement of the quality of technology subsequent to its innovation, then their characterization suggests that an inside innovator's total production cost falls with a higher technology quality (i.e., a smaller value of *k*).

2.3 Royalty licensing

We now examine foreign licensor's decision under royalty licensing. The licensing game under per-unit royalty scheme is summarized as follow. Foreign licensor first chooses the quality of licensed technology. Given the chosen quality, foreign licensor proposes the domestic licensee a royalty contract specifying the per-unit royalty rate and the quality. The licensee accepts this royalty contract if it is not worse off than no licensing, and rejects otherwise. The two firms finally compete in the domestic output market. Notice that foreign licensor (firm 1) cannot collect royalty for the licensee's (firm 2's) production since imitation is possible under weak domestic patenting, it follows that royalty licensing can be implemented only under *SP*, and that it is not feasible under *WP*.

To find the *SPE* outcome of optimal quality of licensed technology, we first solve, under royalty licensing, for the equilibrium output in the market. It is easy to verify that the equilibrium profit of firm 1 and 2, respectively, is

$$\pi_1^R = \frac{(1+c-s+r)^2}{9} + \frac{3r(1-2c+2s-2r)}{9} \qquad (7)$$

$$\pi_2^R = \frac{(1-2c+2s-2r)^2}{9}. \qquad (8)$$

Given the strong patenting system in the licensee country, foreign firm 1 decides the quality $s \in [0, c]$ of its technology for solving Equation (7) subject to

$$\pi_1^R = (q_1^R)^2 = \left(\frac{1+(c-(s-r))}{3}\right)^2 > 0 \text{ and } \pi_2^R = (q_2^R)^2 = \left(\frac{1-2(c-(s-r))}{3}\right)^2 > 0, \quad (IR)$$

$$\pi_2^R > \pi_2^{NL} \equiv \frac{(1-2c)^2}{9} \quad under \quad SP \qquad (IC)$$

Clearly, individual rationality (*IR*) suggests that foreign licensor sets royalty rate $r^* = \frac{5-4c+4s}{10}$ to solve for Equation (7). Nevertheless, incentive compatibility (*IC*) implies, for any $c > 0$ and $r \geq 0$, that the licensee's marginal cost *ex post* licensing remains to be no smaller than the one prior to licensing in order to induce royalty licensing. Hence, we have established that $r \leq s$. [14] This implies the equilibrium royalty is

$$r^* = s. \text{[15]} \qquad (9)$$

Finally, given the equilibrium royalty obtained in Equation (9), foreign licensor chooses at stage 1 the quality of licensed technology to solve for

$$\pi_1^R = \frac{(1+c)^2 + 3s(1-2c)}{9} - \frac{\gamma s^2}{2}. \qquad (10)$$

Substituting (9) into (10) and solve for the *SPE* outcome of quality for the licensed technology, we have

$$s^R = \frac{1-2c}{3\gamma}. \qquad (11)$$

where $s^R > 0$ for any $c < 1/2$ and $\gamma > 0$ due to the second-order condition.

Proposition 2 summarizes foreign licensor's choices of technology quality under royalty licensing scheme.

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[14] The licensee (firm 2) has no incentive to use the licensed technology if the *ex-post* licensing contract is such that $c-(s-r) > c$. It follows that the constraint $r \leq s$ must hold.

[15] The equilibrium royalty of $r^* = (5-4c+4s)/10$ is obtained from solving Equation (7). For any $s \in [0,c]$ and $c < 1/2$, it is easy to verify that $r^* = (5-4c+4s)/10 < s$ if and only if $s > 1/2$, and that $s > 1/2$ violates $s \in [0,c]$ and $c < 1/2$. Hence, the royalty rate in equilibrium must bind and is, therefore, given by $r^* = s$.

Proposition 2 *Given strong patenting* (*SP*) *in the licensee country, foreign firm 1*
(a) conducts royalty licensing if the licensee is relatively cost competitive (*i.e., when its marginal cost is not too high,* $c < 1/2$); *and*
(b) transfers (i) the "state-of-the-art" (*or the frontier*) *quality of its technology at* $s^R = c$ *for any* $\gamma \le (1-2c)/3c$, *but (ii) not the best quality level of* $s^R = (1-2c)/3\gamma < c$ *for any* $\gamma > (1-2c)/3c$.

Under royalty licensing, Proposition 2 suggests that foreign licensor always licenses its technology if the licensee is fairly cost competitive (i.e., $c < 1/2$) and that the best quality of his technology is licensed if the transfer efficiency is sufficiently high (i.e., $\gamma \le (1-2c)/3c$). In the extreme of a very high level of efficiency in technology transfer, implying a negligible total technology transfer cost (when γ approximates 0), the best quality of technology is always transferred since the aggregate of firm 1's profit and royalty revenue strictly increases with a higher level of quality *s*.[16]

Table 3 summarizes the result contained in Proposition 2, given $c < 1/2$ and $\gamma > (1-2c)/3c$.

Table 3 $s^R < c$, $c < 1/2$ and $\gamma > (1-2c)/3c$

s^R	γ	c
0.333	0.3	0.35
0.222	0.3	0.4
0.111	0.3	0.45
0.166	0.6	0.35
0.111	0.6	0.4
0.055	0.6	0.45
0.076	1.3	0.35
0.051	1.3	0.4
0.025	1.3	0.45

Figure 3 shows, under royalty licensing, that the higher the value of γ, the lower the quality of licensed technology, where γ is an arbitrary number satisfying $\gamma > (1-2c)/3c$ for any $c < 1/2$ and $\gamma = 0.3$, $\gamma' = 0.6$ and $\gamma'' = 1.3$.

[16] This is evident, from Equation (10), that $\partial \pi_1^R / \partial s >> 0$ for any $s \in [0, c]$ and $c < 1/2$ if γ approximates zero.

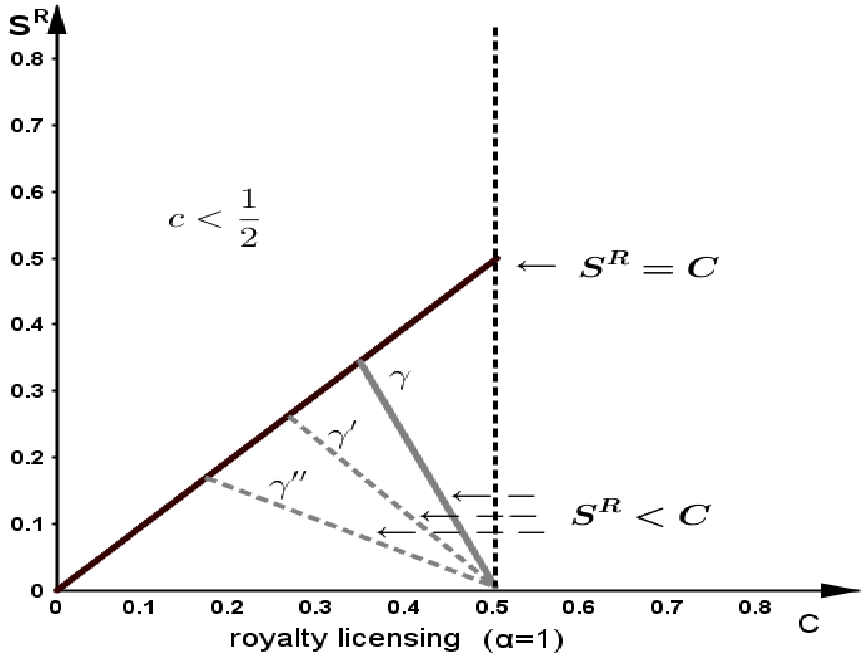

Figure 3 *Strong patenting* ($\alpha = 1$) with $\gamma = 0.3$, $\gamma' = 0.6$ and $\gamma'' = 1.3$.

Notably, this result under royalty licensing is milder than that under fixed-fee licensing as characterized in Proposition 1. Intuitively, royalty licensing directly affects the licensee's marginal cost,[17] given the endogenously determined quality of licensed technology. Hence, royalty licensing can emerge as an equilibrium scheme only when the quality of licensed technology allows the licensee for sufficiently strong competitiveness. It is important to note, however, that the efficiency of technology transfer remains a key element of the quality choice of licensed technology.

In Section 3, we shall compare and study the conditions under which fixed fee licensing or royalty licensing can emerge as an equilibrium scheme. We investigate foreign firm 1's choices of the licensing scheme with reference to its profit under *WP* and *SP* in the licensee country, respectively. And we also study the welfare implications for foreign firm's licensing choices of the domestic patenting systems.

[17] Colombo and Filippini (2016) distinguish ad valorem royalty from revenue royalty and argue that "revenue royalty" allows the patentee for extracting a quota of the licensee's revenues.

To this end, we restrict our discussion to any c and α such that $c < 1/5\alpha$ under which both licensing schemes take place (cf. Propositions 1 and 2).

3. The Main Results

3.1 Domestic IPRs system and the equilibrium licensing schemes

A qualitative comparison of the results contained, respectively, in Proposition 1, Corollary 1 and Proposition 2 indicates, under both licensing schemes, that the quality of technology at the "state-of-the-art" level is always licensed so long as the burden of making its technology available to the licensor is not too excessive and the licensee's generic technology is not too much behind that of the licensor, which is captured by an insignificant cost differences between the licensor and the licensee.

Next, under strong *IPR*s system in the licensee country, the constraints in which technology transfer takes place under royalty licensing is less restrictive than that under fixed-fee licensing. Indeed, under royalty licensing, $s^R > 0$ for any $c < 1/2$; and under fixed-fee licensing, $s^F > 0$ if $c < 1/5$. We note, under *WP* in the licensee country, that royalty licensing scheme is not an equilibrium strategy for the licensor due to possible imitation. Hence, we restrict our comparison of the two schemes under *SP*. Nonetheless, this key feature of our model justifies our analysis into fixed fee licensing and royalty licensing, in contrast to Mukherjee and Tsai (2015) and others. Our consideration of possible imitation taking place in the licensee country with weak *IPR*s system implies that a general model of two-part tariff licensing scheme collapses into a fixed-fee scheme. This consideration of linking domestic *IPR*s system with royalty licensing scheme through imitation allows for separation of our model from other previous ones. Consequently, royalty licensing and its applicability can serve as an indicator of the domestic patenting regime in the licensee country.

3.2 Equilibrium firm profits under two licensing schemes

For any domestic patenting system in the licensee country, Propositions 1 and 2 and Corollary 1 suggest that net profit of foreign licensor (firm 1) and domestic licensee (firm 2) under fixed-fee licensing is, respectively, given by

$$\pi_1^F = \begin{cases} \dfrac{9\gamma(1+\alpha c)^2 - 8(1+5\alpha c - 5\alpha^2 c^2)}{9(9\gamma - 10)}, & \textit{under WP} \quad \textit{if} \quad \alpha > \dfrac{2}{9\gamma c} \\ \dfrac{2-(1-2\alpha c)^2}{9} - \gamma \dfrac{\alpha^2 c^2}{2}, & \textit{under WP} \quad \textit{if} \quad \alpha < \dfrac{2}{9\gamma c} \end{cases}, \tag{12a}$$

$$\pi_1^F = \begin{cases} \dfrac{9\gamma(1+c)^2 - 8(1+5c - 5c^2)}{9(9\gamma - 10)}, & \textit{under SP} \quad \textit{if} \quad \gamma > \dfrac{2}{9c} \\ \dfrac{2-(1-2c)^2}{9} - \gamma \dfrac{c^2}{2}, & \textit{under SP} \quad \textit{if} \quad \gamma > \dfrac{2}{9c} \end{cases}, \tag{12b}$$

$$\pi_2^F = \begin{cases} \dfrac{(1-2\alpha c)^2}{9}, \textit{under WP} \\ \dfrac{(1-2c)^2}{9}, \textit{under SP} \end{cases}. \tag{12c}$$

Using Proposition 2, it is easy to show, under royalty licensing, that the net profit of firm 1 and 2 is, respectively, given by

$$\pi_1^R = \frac{(1-2c)^2 + 2\gamma(1+c)^2}{18\gamma}, \qquad \textit{for any } \frac{1-2c}{3c} < \gamma \tag{13a}$$

$$\pi_1^R = \frac{1+5c(1-c)}{9} - \gamma\frac{c^2}{2}, \qquad \textit{for any } 0 \le \gamma \le \frac{1-2c}{3c} \tag{13b}$$

$$\pi_2^R = \frac{(1-2c)^2}{9}. \tag{13c}$$

Proposition 3 below characterizes the conditions under which fixed-fee emerges as the equilibrium licensing scheme under *SP* in the licensee country.

Proposition 3 *In the subgame perfect equilibrium* (*SPE*), *foreign licensor adopts* (*i*) *fixed-fee licensing when both the transfer of his technology is relatively efficient* ($\frac{10}{9} < \gamma < \frac{1-2c}{3c} < \frac{2}{9c}$) *and the licensee is sufficiently competitive in the domestic market* ($1/6 < c < 3/16$); *and* (*ii*) *royalty licensing, otherwise*.

Proof. See Appendix A.

Intuitively, even though a strong patenting in the licensee country may safeguard the licensor's business interests, the licensor's decisions rest upon the trade-offs between his cost advantage against that of the licensee and the burden of technology transfer costs, which, in turn, fall with a higher level of efficiency. Using Equations (12c), it is evident, under fixed-fee licensing, that the licensee (firm 2) secures a higher profit in the presence of weak domestic patenting regime, and that the licensee's profit under fixed-fee licensing in the presence of strong domestic *IPR*s equals to that is obtained under royalty (cf. Equation (12c) and (13c)). Notice, however, that a weak domestic *IPR*s system prevents the licensor from engaging in royalty licensing. It is, therefore, illegitimate to compare the licensee's equilibrium profit under royalty to that is established under fixed-fee in the presence of weak domestic patenting regime.[18]

3.3 Domestic welfare in the licensee country

We have shown, using Proposition 1 and Corollary 1, that domestic welfare in the licensee country under fixed-fee licensing with weak patenting (denoted by W_W^F) and that with strong patenting (denoted by W_S^F) is, respectively, given by

$$W_W^F = \begin{cases} \dfrac{9[(2-\alpha c)\gamma - 2]^2 + 2(1-2\alpha c)^2(9\gamma-10)^2}{18(9\gamma-10)^2}, & if\ \dfrac{2}{9\gamma c} < \alpha \\ \dfrac{3-4\alpha c+4\alpha^2 c^2}{9}, & if\ \dfrac{10}{9} < \alpha < \dfrac{2}{9\gamma c} \end{cases} \quad (14a)$$

$$W_S^F = \begin{cases} \dfrac{9[(2-c)\gamma - 2]^2 + 2(1-2c)^2(9\gamma-10)^2}{18(9\gamma-10)^2}, & if\ \dfrac{2}{9c} < \gamma \\ \dfrac{3-4c+4c^2}{9}, & if\ \dfrac{10}{9} < \gamma < \dfrac{2}{9c} \end{cases} \quad (14b)$$

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[18] The authors thank an anonymous referee for raising this issue.

Intuitively, fixed-fee licensing implies foreign licensor extracts the entire rent if it decides to license on the one hand, and domestic licensee only produces if the quality of the licensed technology allows for its competition in the domestic market on the other. It follows that a weaker domestic patenting system gives rise to a higher welfare in the licensee country under fixed-fee licensing regardless the efficiency of technology transfer since consumer surplus in the licensee country rises when both firms produce in the southern market.

Further, using Proposition 2, it is evident that the welfare in the licensee's country under royalty licensing is $W^R = \frac{2(1-2c)^2 + (2-c)^2}{18}$ irrespective of the efficiency of technology transfer. An intuitive explanation for this result can be provided as follows. Under royalty licensing, the quality of licensed technology is chosen to be commensurate with royalty per unit of the licensee's output. In equilibrium, the quality of licensed technology ought to be chosen in a way such that the licensee's cost *ex post* licensing allows for its participation in the output market while the patenting system in the licensee country can affect no longer the equilibrium profit and, thus, domestic welfare.

In order to bring out the main message of our analysis, we focus on the implication of strong *vs*. weak domestic *IPR*s system in the licensee country for the welfare in the licensor country. Proposition 4 below summarizes our analysis for the impact of domestic patenting system on foreign welfare.

Proposition 4 *With endogenous choice of the quality for licensed technology, welfare in the licensor's country need not unambiguously rise with stronger domestic IPRs in the licensee country. More precisely, welfare in the licensor's country falls with the strength of domestic IPRs if such system in place is already sufficiently lax* (i.e., $\alpha \le \tilde{\alpha}$) *and rises with it otherwise* (i.e., $\alpha \le \tilde{\alpha}$).

Proof. See Appendix B.

In the presence of endogenous quality choice, technology licensing takes place whenever the rent to foreign licensor generating from such agreement outweighs the losses in outputs under weak domestic patenting system in the licensee country.[19] This suggests, if the efficiency of technology transfer (as captured by the slope of the marginal cost of technology transfer) is sufficiently high and the primary cost differences between the firms are sufficiently small, that a weaker *IPR*s in the licensee country need not always hamper welfare of the licensor country under fixed fee licensing. Indeed, if the efficiency of technology transfer is high, foreign licensor can easily license technology of higher grade (or better quality) to licensee under fixed-fee licensing. Under such circumstance, the higher net profit of the licensor under fixed fee licensing allows for a relatively beneficial effect of the consumers surplus in the licensee country and, thus, leads to a greater domestic welfare under fixed fee licensing.

4. Conclusion

We investigate the impact of domestic patenting regime on a foreign licensor's decisions over technology quality and optimal licensing scheme, in contrast to the early patenting literature wherein welfare implications of patenting have been the focal point. While attempting to contribute to the extant literature, we examine licensing decision with endogenous choice over the quality of licensed technology. We consider its closeness to the "state-of-the-art" level as the quality of licensed technology. We use the strength of domestic patenting systems in the licensee country

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[19] This is evident from the unambiguously negative impact on licensor's output of a lax domestic *IPRs* system, i.e., $\frac{\partial^2 y_1^F}{\partial \alpha^2} = \frac{2}{9}(c - \frac{\partial s^F}{\partial \alpha})^2 > 0$, and the ambiguous effect on the gains from licensing, $\frac{\partial^2 F^*}{\partial \alpha^2} = \frac{2}{9}\left[(-2)\left\{(-2c + \frac{-10c}{9\gamma - 10})\frac{9\gamma c}{9\gamma - 10} - (-2c^2)\right\}\right] \underset{<}{\overset{>}{}} 0$, which obviously rests upon the interplays between efficiency of technology transfer and post-licensing marginal cost of the licensee.

as an equivalent to the possibility of imitation *ex post* licensing. And we separate the domestic *IPRs* system in the licensee country into the categories of weak patenting and strong patenting under both fixed fee licensing and royalty licensing. Our treatment that weak domestic patenting in the licensee country excludes foreign licensor from implementing royalty licensing facilitates the features of our model, namely, weak patenting in the domestic market pre-conditions the threat of competition from the licensor and, thus, constrains the 'quality' of licensed technology that can be chosen. This formulation allows for the linkages between intellectual property protection regime and licensing decisions on the one hand, and the endogenous choice of licensed technology quality under different licensing schemes on the other. Our analysis has shown that fixed fee emerges as the equilibrium licensing scheme when both the transfer of his technology is relatively efficient and the licensee is sufficiently cost competitive in the domestic market, and that royalty licensing prevails otherwise. This qualitative aspect of transferring "state-of-the-art" technology holds for both strong and weak *IPR*s system in the licensee country. We have also shown, under royalty licensing, that the best quality of its technology is licensed provided the efficiency of technology transfer is sufficient high and the domestic *IPR*s regime in the licensee country is sufficiently strong.

For the possible avenue of future research, it is worth emphasizing that interesting insights can be provided to the extant literature as to whether quality choice of the licensed technology can be functioned as a cost-reducing technology[20] or whether new result can be obtained if it is alternatively formulated as a demand enhancing element[21], despite that royalties is not directly associated with price in Colombo and Filippini (2016) and our paper focuses on the endogenous quality choice for any given strength of the domestic *IPR*s system.

[20] The authors thank an anonymous referee for raising this issue.
[21] See Levhari and Peles (1973) for a justification on this characterization.

To conclude, we have identified licensing through endogenous quality choice of licensed technology as the main channel, in contrast to those considered in the literature such as economies of scale and entry mode choices. This important insight can provide licensee's government in formulating intellectual property policy prescriptions while inducing the frontier technology from the licensor.

Appendix A

Notice, under a strong patenting system in the licensee country, that fixed-fee licensing emerges as the equilibrium scheme if and only if $\pi_1^F > \pi_1^R$. Using Equations (12a) - (12c) and (13a) - (13c), it is easy to verify, for any of the following conditions: (i) $\gamma > \max\left\{\frac{2}{9c}, \frac{1-2c}{3c}\right\} = \frac{2}{9c}$ and $c \in (1/6, 1/5)$, (ii) $\gamma > \max\left\{\frac{2}{9c}, \frac{1-2c}{3c}\right\} = \frac{1-2c}{3c}$ and $c \in (0, 1/6)$ (cf. Equations (12a) and (13a)), (iii) $\gamma < \min\left\{\frac{2}{9c}, \frac{1-2c}{3c}\right\} = \frac{2}{9c}$ and $c \in (0, 1/6)$, and (iv) $\gamma < \min\left\{\frac{2}{9c}, \frac{1-2c}{3c}\right\} = \frac{1-2c}{3c}$ and $c \in (1/6, 1/5)$ (cf. Equations (12b) and (13b)), that $\pi_1^F > \pi_1^R$ if and only if $Z > 0$, where

$$Z \equiv \left[\frac{(1-2c+2s^F)^2 - (1-2c)^2}{9} - \frac{3s^R(1-2c)}{9}\right] + \left[\frac{(1+c-s^F)^2}{9} - \frac{(1+c)^2}{9}\right] - \frac{\gamma}{2}\left[(s^F)^2 - (s^R)^2\right], \tag{A-0}$$

To prove the result contained in Proposition 3, we sketch our proof by contradiction and proceed in three steps.

Proof. First, given the *SPE* outcome of s^F and s^R, we rewrite *Z* as

$$Z \equiv \underbrace{\left[\frac{4(1-2c)s^F + 4[(s^F)^2 - (1-c)s^R] + s^R}{9}\right]}_{\Delta} + \underbrace{\left[\frac{[(1+c-s^F)+(1+c)]}{9} - \frac{[(1+c-s^F)-(1+c)]}{9}\right]}_{\Omega>>0} - \frac{\gamma}{2}\underbrace{\left[(s^F)^2 - (s^R)^2\right]}_{\Psi}, \tag{A-1}$$

and we note that *Z* consists of three terms Δ, Ω and Ψ, where Ω is strictly positive and Ψ is nonnegative if $s^F - s^R \geq 0$. Hence, Z is strictly positive provided that Δ is non-negative. It is evident, for any $s^F - s^R > 0$, that Δ is strictly positive if and only if

$$(1-2c) + \frac{s^R}{4s^F} > -[(1-c)(1-\frac{s^R}{s^F}) + (s^F - c)]. \tag{A-2}$$

Rewriting Equation (A-2), we have $\frac{s^R}{4(1-c)s^F} + \frac{4(1-c)(s^F - s^R)}{4(1-c)s^F} > \frac{4s^F(1-c-s^F)}{4(1-c)s^F}$, i.e., $4(s^F)^2 - [4(1-c)-1]s^R > 0$. Given s^R, it is evident that Δ is strictly convex in s^F. Hence, Δ rises with an increase in s^F for any $s^F \in [s^{F^*}, c)$, where $s^{F^*} \equiv \frac{\sqrt{(3-4c)s^R}}{2}$. Note the sign of $s^F - s^R$ is decisive in identifying that of Z, we investigate further in the next two steps.

Second, we note that $s^F - s^R < 0$ occurs if $s^F \equiv \frac{2(1-5c)}{9\gamma - 10} < c$ for any $\frac{10}{9} < \frac{2}{9c} < \gamma$ and $c \in (1/6, 1/5)$ and $s^R = c$ for any $\gamma \leq \frac{1-2c}{3c}$ and $c \in (1/6, 1/5)$. The boundary conditions of $\frac{2}{9c} < \gamma$ and $\gamma \leq \frac{1-2c}{3c}$, however, violates $c \in (1/6, 1/5)$. Hence, $s^F - s^R < 0$ does not hold. Next, we study whether or not $s^F - s^R \geq 0$ can hold. It is evident $s^F = c$ for any $c \in (0, 1/5)$ and $\frac{10}{9} < \gamma \leq \frac{2}{9c}$, and $s^R = \frac{1-2c}{3\gamma} < c$ for any $\gamma > \frac{1-2c}{3c}$ and $c \in (0, 1/6)$. Again, the boundary conditions of $\frac{2}{9c} < \gamma$ and $\gamma > \frac{1-2c}{3c}$ fails to meet the condition of $c \in (0, 1/6)$.

Third, we then examine whether or not $s^F - s^R \geq 0$ given that $s^F = c$ for any $c \in (0, 1/5)$ and $\frac{10}{9} < \gamma \leq \frac{2}{9c}$, and $s^R = c$ for any $\gamma \leq \frac{1-2c}{3c}$ and $c \in (1/6, 1/5)$. It is easy to verify that $s^F - s^R \geq 0$ if and only if $\frac{10}{9} < \gamma < \frac{1-2c}{3c} < \frac{2}{9c}$ and $c \in (1/6, 3/16)$.

Hence, we have established that $\pi_1^F > \pi_1^R$ if and only if $\frac{10}{9} < \gamma < \frac{1-2c}{3c} < \frac{2}{9c}$ and $c \in (1/6, 3/16)$. ■

Appendix B

Welfare in the licensor's country is now simplified to $W_N^F = \pi_1^F$. Using Equations (5) and (6), we differentiate π_1^F with respect to α and obtain that

$$\frac{dW_N^F}{d\alpha} \equiv \frac{d\pi_1^F}{d\alpha} = \frac{dy_1^F}{d\alpha} + \frac{dF^*}{d\alpha} - \gamma s^F \frac{ds^F}{d\alpha}. \tag{B-1}$$

where

$$\frac{\partial y_1^F}{\partial \alpha} = \frac{2}{9}(1 + \alpha c - s^F)(c - \frac{\partial s^F}{\partial \alpha}), \text{ and}$$

$$\frac{\partial F^*}{\partial \alpha} = \frac{2}{9}\left[(1 - 2\alpha c + s^F)(-2)(c - \frac{\partial s^F}{\partial \alpha}) - (1 - 2\alpha c)(-2c)\right].$$

Using the results contained in Propositions 1 and 2, we have

$$\frac{\partial s^F}{\partial \alpha} = \begin{cases} \dfrac{-10c}{9\gamma - 10}, & \forall \quad \dfrac{2}{9\gamma c} < \alpha < \dfrac{1}{5c} \\ \quad c \quad , & \forall \quad \dfrac{10}{9c} < \alpha < \dfrac{2}{9\gamma c} \end{cases},$$

$$\frac{\partial y_1^F}{\partial \alpha} = \begin{cases} \dfrac{2(1+\alpha c - s^F)}{9}\dfrac{9\gamma c}{9\gamma - 10}, & \forall \ \dfrac{2}{9\gamma c} < \alpha < \dfrac{1}{5c} \\ \qquad 0 & , \forall \ \dfrac{10}{9\gamma} < \alpha < \dfrac{2}{9\gamma c} \end{cases} \text{, and}$$

$$\frac{d\pi_1^F}{d\alpha} = \frac{2}{9}\left[(1+\alpha c - 5s^F)\underbrace{(c - \frac{\partial s^F}{\partial \alpha})}_{\geq 0} + 2(1-2\alpha c)\frac{\partial s^F}{\partial \alpha}\right] - \gamma s^F \frac{\partial s^F}{\partial \alpha}.$$

Hence, we have established that

$$\frac{d\pi_1^F}{d\alpha} = \begin{cases} \dfrac{2c}{9(9\gamma - 10)^2}\omega \quad , & \forall \quad \dfrac{2}{9\gamma c} < \alpha < \dfrac{1}{5c} \\ \dfrac{4c - (8+9\gamma)\alpha c^2}{9}, & \forall \quad \dfrac{10}{9\gamma} < \alpha < \dfrac{2}{9\gamma c} \end{cases}, \tag{B-2}$$

where $\omega = A\alpha + B$, $A = [(9\gamma+4)(9\gamma-10) - 50(9\gamma-1)]c$ and $B = [(9\gamma-2)(9\gamma-10) + 10(9\gamma-1)]$.

It follows that $\frac{d\pi_1^F}{d\alpha} >> 0$ for any $\frac{10}{9\gamma} < \alpha \leq \frac{2}{9\gamma c}$ since $\alpha < \frac{4}{(8+9\gamma)c}$ trivially satisfies the boundary condition, and that, for any $\frac{2}{9\gamma c} < \alpha < \frac{1}{5c}$, $\frac{d\pi_1^F}{d\alpha} < 0$ if $\alpha \leq \tilde{\alpha}$ and otherwise if $\alpha > \tilde{\alpha}$, where $\tilde{\alpha} = \frac{(9\gamma-2)(9\gamma-10)+10(9\gamma-1)}{[(9\gamma+4)(9\gamma-10)-50(9\gamma-1)]c}$ and $\tilde{\alpha} \in (\frac{1}{5c}, 1)$. ■

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