ARTICLE IN PRESS
REVECO-01221; No of Pages 7
International Review of Economics and Finance xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
International Review of Economics and Finance
journal homepage: www.elsevier.com/locate/iref

Tariffs, technology licensing and adoption

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ARTICLE INFO

Available online xxxx

JEL classification:
L13
L24
O33

Keywords:
Licensing
Technology adoption
Tariffs

ABSTRACT

This paper develops a two-country Cournot duopoly model to investigate the implications of international technology licensing. It is shown that if the tariff imposed by the domestic country is high, it is optimal for the foreign firm to adopt an inferior technology for its production when it licenses its most advanced technology to the domestic firm. Such a licensing arrangement may improve welfare of the two countries.

1. Introduction

It is commonly believed that a producer with a superior technology in hand has no incentive to adopt an inferior technology since the inferior technology decreases the firm's production efficiency and hence its profits.[1] However, this is not true if the firm can license its technology to its rivals. There are empirical evidences in support of this argument. For example, one of Samsung's high-end smart phone, the S6, is known to use Sony's newest and most superior sensor (model IMX240), which has never appeared in the latter's own products.[2] Another example is the Apple A5 (a chip using a 32 nm process, model S5L8942), which was manufactured by Samsung and used in the iPad2 in March 2012. However, it was not until August 2012 that Samsung adopted the same production process to produce its own tablet computer.[3] These cases indicate that a licensor firm might use an inferior technology for its own production, yet its theoretical underpinning has never been explored. In this paper we shall provide a theoretical model to explain why a licensor firm has an incentive to adopt an inferior technology even if a superior technology is available at no cost.

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[1] Shieh and Peng (2000) is an exception. They employ a vertical product differentiation model in which firms compete in Bertrand competition and find that in order to soften price competition, a firm has an incentive to produce a low-quality product. Their setting and approach are very different from ours.

[2] Please refer to http://image-sensors-world.blogspot.tw/search?q=imx240.

[3] Please refer to http://en.wikipedia.org/wiki/Apple_A5#cite_note-23.

http://dx.doi.org/10.1016/j.iref.2016.02.012
1059-0560/

Please cite this article as: Chen, H.-L., et al., Tariffs, technology licensing and adoption, *International Review of Economics and Finance* (2016), http://dx.doi.org/10.1016/j.iref.2016.02.012

Technology licensing is a topic which has attracted much attention during the last two decades.[4] It discusses how a technologically advanced firm licenses its superior technology to a technologically backward rival (see, for example, Wang, 1998; Wang, 2002; Wang & Yang, 1999; Fauli-Oller & Sandonis, 2002, and Poddar & Sinha, 2010).[5] It is shown that the optimal licensing contract involves the use of a royalty (fixed fee) if a licensor firm and a licensee firm compete in a common market and their products exhibit high (low) substitutability. This is because if the two products exhibit high substitutability, the licensor firm can use a royalty to weaken competition from the licensee firm and is thus preferable to fixed-fee.

Furthermore, Kabiraj and Marjit (2003); Mukherjee and Pennings (2006), and Mukherjee (2007), have analyzed the policy implications of technology licensing in an international context. Kabiraj and Marjit (2003) set up a three-stage model to show that a government can use an import tax to induce a foreign high-tech firm to license its technology to a domestic firm via a fixed-fee licensing contract, thereby increasing its consumer surplus and social welfare. Mukherjee and Pennings (2006) find that a tax policy imposed by a domestic country could encourage a foreign monopolist to license its advanced technology to domestic firms and this practice can increase the social welfare of the domestic country. Mukherjee (2007) analyzes the optimal licensing contract between a foreign licensor firm and a domestic licensee firm when the foreign firm competes with the domestic firm in the domestic market. He shows that the optimal licensing contract for the foreign licensor is a royalty (fixed-fee) if the trade cost is sufficiently low (high), while the combination of fixed-fee and royalty licensing is optimal if the trade cost is moderate.

While each of these papers has enriched the literature, their results depend on the following simplified assumptions that both the licensor and the licensee use the same technology after licensing.[6] However, as mentioned above, in reality, the technology employed by a licensor firm may be inferior to the technology adopted by the licensee firm. The purpose of this paper is to provide a theoretical rationale for this behavior and to analyze the corresponding effect on welfare. Hence, we will ask the following questions in this paper: (i) Why does a foreign licensor have the incentive to adopt an inferior technology even if a superior technology is available at no cost? (ii) Does trade liberalization always increase trade volume and consumer welfare as believed usually?

The key innovation of the paper is that there are cases in which the foreign licensor firm adopts an inferior technology for its own production when it is determined to license its most advanced technology to its competitor. This inferior technology adopted by the foreign firm increases consumer surplus and welfare of the licensee firm's country.

The remainder of this paper is organized as follows. Section 2 outlines the model and shows technology adoption by the foreign firm. Section 3 compares social welfare under different technologies of the foreign firm. Section 4 concludes.

2. The model

Assume that there are two countries, called, domestic and foreign. There is a firm in each country—domestic firm (in the domestic country) and foreign firm (in the foreign country). The firms produce homogeneous goods and compete in Cournot fashion in the domestic market. The inverse demand for the good is $p = p(Q)$, with $Q = q + q^*$, $p' < 0$, where q^* represents the amount of export by the foreign firm to the domestic market and q is the output of the domestic firm. We assume that the domestic firm possesses a technology corresponding to the marginal cost c and the foreign firm possesses a technology corresponding to the marginal cost $c - \theta$, where θ belongs to $[0, \overline{\theta}]$. Thus, the foreign firm's marginal cost is $c\text{-}\overline{\theta}$ if it adopts the most superior technology for its own production, but the cost remains at c if it adopts the most inferior one. The foreign firm also needs to pay a per-unit tariff, t, for its exports to the domestic country. Following the literature on technology licensing, we further assume that the foreign firm licenses, via a two-part tariff contract, i.e., a fixed fee (F) and a royalty rate (r), its *most superior* technology to the domestic firm.[7] Hence, the domestic firm's marginal cost after licensing is $c - \overline{\theta} + r$.

The game in question consists of three stages. In the first stage, the foreign firm chooses the optimal technology for its own production.[8] In the second stage, given the adopted technology, the foreign firm licenses its most superior technology to the domestic firm through a two-part tariff (a royalty rate and a fixed fee) licensing contract, followed by the domestic firm's move to accept the offer or not.[9] In the third stage, the two firms produce their outputs simultaneously for the domestic market and the profits are realized. As usual, we shall solve the game through backward induction.

The profit functions of the foreign and the domestic firms are expressed respectively as follows:

$$\pi^*(q^*, q; r, F, \theta) = p(Q)q^* - (c - \theta)q^* - tq^* + rq + F, \tag{1}$$

[4] Nadiri (1993) shows that international payments for patents, licenses and technical know-how for Japan, the U.K. France and the U.S. were growing substantially between 1979 and 1988. Moreover, Maskus (2015) provides an excellent review on the effects of IPRs on innovation, trade and technology transfer.

[5] According to Rostoker (1984), royalty licensing alone was used 39% of the time, fixed-fee licensing alone 13% of the time, and royalty and fixed-fee licensing 46% of the time, among the firms surveyed.

[6] In the literature, it is common to assume that the level of innovation is exogenous. See, for example, Kabiraj and Marjit (2003) and Mukherjee (2007); Chang and Peng (2013) and Nabin and Sgro (2013). However, some papers regard the innovation level as endogenous (Rockett, 1990; Kabiraj & Marjit, 1993; Chang, Hwang, & Peng, 2013, and Hwang, Marjit, & Peng, 2015).

[7] The result that a licensor firm licenses its most superior technology to a licensee firm is well documented in the literature. See, for example, Rockett (1990) and Kabiraj and Marjit (1993).

[8] In this game, we assume that the foreign firm can determine and commit to the adopted technology before its licensing and output decisions.

[9] Strictly speaking, there are two subgames in the second stage of the game—one with the domestic licensee firm accepting the licensing arrangement, and the other with the domestic licensee firm rejecting the offer. As the domestic licensee firm would always accept the arrangement in the equilibrium, we shall consider only the first subgame.

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$$\pi(q^*, q; r, F, \theta) = p(Q)q - (c - \overline{\theta})q - rq - F. \quad (2)$$

By differentiating (1) and (2) with respect to q^* and q respectively, we can derive the first-order conditions for profit maximization as follows:

$$\pi^*_{q^*} = p - (c - \theta + t) + p'q^* = 0, \quad (3)$$

$$\pi_q = p - (c - \overline{\theta} + r) + p'q = 0. \quad (4)$$

The second-order and the stability conditions for profit maximization are as follows:

$$\pi^*_{q^*q^*} = 2p' + p''q^* < 0, \pi_{qq} = 2p' + p''q < 0, \text{ and } H = \pi^*_{q^*q^*}\pi_{qq} - \pi^*_{q^*q}\pi_{qq^*} > 0.$$

Moreover, we also assume that the slopes of the reaction functions of the domestic and the foreign firms are both negative, which require $\pi^*_{q^*q} = p' + p''q^* < 0$ and $\pi_{qq^*} = p' + p''q < 0$. From the above conditions, we can get the following comparative static effects as:

$$q^*_t = \pi_{qq}/H < 0, \;\; q_t = -\left(\pi_{qq^*}\right)/H > 0, \quad (5a)$$

$$q^*_r = -\left(\pi^*_{q^*q}\right)/H > 0, \quad q_r = \pi^*_{q^*q^*}/H < 0, \quad (5b)$$

$$q^*_\theta = -\pi_{qq}/H > 0, q_\theta = \left(\pi_{qq^*}\right)/H < 0. \quad (5c)$$

These conditions show that the output of the foreign firm decreases with tariff, but it increases with its technology level, θ, or the royalty rate, whereas the domestic firm's output decreases with the technology adopted by the foreign firm or the royalty rate. The intuition behind these results is straightforward. An increase in the foreign firm's marginal cost or the tariff makes the foreign firm (the domestic firm) less (more) competitive, and thus produces less (more). The intuition for the changes with respect to the royalty rate can be similarly derived.

Now let us move to the second-stage of the game and derive the optimal fixed-fee and royalty rate. Following the literature, we assume that the foreign licensor firm is capable of extracting the entire rent generated from licensing.[10] Thus, the optimal fixed fee charged by the foreign firm is defined as follows:

$$F = (p(Q(r, \theta)) - c + \overline{\theta} - r)q(r, \theta) - \left(p^N\left(Q^N(\theta)\right) - c\right)q^N(\theta), \quad (6)$$

where the first and second terms on the RHS represent the profits of the domestic firm post- and pre-licensing, respectively, for a given θ that is being determined by the foreign firm in stage one of the game. Variables with a superscript "N″" are associated with the no-licensing regime. We see from (6) that the fixed fee is a function of r. Similarly, we can derive from (3) and (4) that q^* and q are functions of r. Substituting them into (1), we can rewrite the objective function of the foreign firm for the second-stage game as follows:

$$\underset{r}{\text{Max}} \;\; \pi^*(Q(r), F(r), r) = (p(Q(r)) - c + \theta - t)q^*(r) + rq(r) + F(r). \quad (7)$$

By differentiating (7) with respect to r and utilizing (3) and (4), we can derive the first-order condition for profit maximization as follows:

$$\begin{aligned} \frac{d\pi^*}{dr} &= \frac{\partial \pi^*}{\partial q}\frac{\partial q}{\partial r} + \frac{\partial \pi^*}{\partial r} + \frac{\partial \pi^*}{\partial F}\frac{\partial F}{\partial r} \\ &= \underset{\text{strategic effect}}{(p'q^*)q_r} + \underset{\text{licensing revenue effect}}{\left[rq_r + (p'q)q^*_r\right]} = 0. \end{aligned} \quad (8)$$

The second-order condition for profit maximization requires that

$$\pi^*_{rr} = p''Q_r(q^*q_r + qq^*_r) + p'[q^*q_{rr} + qq^*_{rr}] + 2p'q_rq^*_r + q_r < 0.$$

[10] This is a standard assumption in the literature; see, for example, Wang (1998) and Kabiraj and Marjit (2003), among others.

The sign of π^*_{rr} is ambiguous, depending on p'''. However, if we assume that the market demand is linear, it reduces to $\pi^*_{rr}=2p'q_rq^*_r+q_r=2/9p'<0$, which implies that the second-order condition is satisfied. We shall assume that this is the case for the rest of the analysis. By totally differentiating (6) and (8) with respect to r, t, and θ, we can obtain the following comparative static results:

$$r_t=\frac{-\pi^*_{rt}}{\pi^*_{rr}}=\frac{-5}{2}<0, \text{and } r_\theta=\frac{-\pi^*_{r\theta}}{\pi^*_{rr}}=\frac{5}{2}>0, \tag{9a}$$

$$F_t=[p'q(q^*{}_rr_t+q^*{}_t)-r_tq]>0, \text{and } F_\theta=[p'q(q^*{}_rr_\theta+q^*{}_\theta)-r_\theta q]<0, \tag{9b}$$

where $\pi^*_{rt}=(p'q^*_t)q_r+(p'q_t)q^*_r=5/9p'$ and $\pi^*_{r\theta}=(p'q^*_\theta)q_r+(p'q_\theta)q^*_r=-5/9p'$. Eq. (9a and 9b) shows that given the linear demand assumption, the optimal royalty rate decreases and the fixed fee increases with tariff, whereas the optimal royalty rate increases but the fixed fee decreases with the foreign firm's technology. The intuition for the aforementioned results is as follows. As the tariff increases, it becomes "too costly" for the foreign firm to serve the market. Instead, the foreign licensor firm can lower the royalty rate to raise the output of the licensee firm and then use a higher fixed fee to extract the rent from the licensee firm. The intuition for the effects of θ on the royalty rate and the fixed fee can be similarly derived. These results are summarized in the following lemma.

Lemma 1. The optimal royalty rate decreases but the optimal fixed fee increases with tariff, while the optimal royalty rate increases but the optimal fixed fee decreases with the technology level of the foreign firm.

We now turn to the first-stage of the game, in which the foreign firm chooses the quality of the technology for its own production. The profit function of the foreign firm becomes:

$$\underset{\theta}{\text{Max}}\ \pi^*(Q(r(\theta),\theta)),r(\theta),F(r(\theta),\theta),\theta) \ =(p(Q(r(\theta),\theta))-c+\theta-t)q^*(r(\theta),\theta)+r(\theta)q(r(\theta),\theta)+F(r(\theta),\theta). \tag{10}$$

By totally differentiating this equation with respect to θ, we can derive the first-order condition for profit maximization as follows:

$$\frac{d\pi^*}{d\theta}=\frac{\partial\pi^*}{\partial q}\frac{\partial q}{\partial\theta}+\frac{\partial\pi^*}{\partial F}\frac{\partial F}{\partial\theta}+\frac{\partial\pi^*}{\partial\theta}=\underset{\text{strategic effect}}{(p'q^*)q_\theta}+\left[\underset{\text{licensing revenue effect}}{rq_\theta+p'(q^*_\theta q)-p'\left(q^{*N}_\theta q^N\right)}\right]+\underset{\text{cost effect}}{q^*}. \tag{11}$$

As shown in (11), there are three effects that jointly determine the foreign firm's optimal technology. The first term, referred to as the strategic effect, is positive. It shows that an increase in the foreign firm's technology lowers the rival's output but increases its own profit. The second term is the licensing-revenue effect, which is negative. The third term, referred to as the cost effect, is positive. It shows that a better technology lowers the cost of the existing output. Overall, the sign of (11) is ambiguous, depending on the forces of the three effects. Furthermore, the second-order condition for profit maximization is positive as

$$\pi^*_{\theta\theta}=2p'q_\theta q^*_\theta+q^*_\theta+(p'q^*_r+1)r_\theta q_\theta+p'q^*_\theta q_rr_\theta+q^*_rr_\theta-p'(q^{*N}_\theta q^N_\theta)>0.$$

This implies that the profit function is U-shaped. The foreign firm's optimal technology has a corner solution. The optimal technology is either the most superior one or the most inferior one, depending on which yields a higher profit. By comparing the profits of the foreign firm at the two technology levels, we can derive the profit difference as follows:

$$\begin{aligned}\Delta\pi^*=\pi^*(\theta^*=0)-\pi^*(\theta^*=\overline{\theta}) &=[p(Q(0))-t-c]q^*(0,t)+r(0)q(r(0))+F(r(0))\\ &-\left[(p(Q(\overline{\theta}))-t-c+\overline{\theta})q^*(\overline{\theta},t)+r(\overline{\theta})q(r(\overline{\theta}),\overline{\theta})+F(r(\overline{\theta}),\overline{\theta})\right].\end{aligned} \tag{12}$$

Setting (12) equal to zero, we get that

$$\underbrace{[p(Q(0))-t-c]q^*(0,t)-\left[p(Q(\overline{\theta}))-t-c+\overline{\theta}\right]q^*(\overline{\theta},t)+}_{\text{the difference of profits}}$$

$$\underbrace{\left[p(Q(0))-c+\overline{\theta}\right]q(0,t)-\left[p(Q(\overline{\theta}))-c+\overline{\theta}\right]q(\overline{\theta},t)-\left[\pi^N(0,t)-\pi^N(\overline{\theta},t)\right]}_{\text{the difference of licensing revenues}}\ \overset{>}{\underset{<}{=}}0, \text{if } t\overset{>}{\underset{<}{=}}\hat{t},$$

i.e., if $t=\hat{t}$, the profits of the foreign firm equipped with the most superior or the most inferior technology are the same. A tariff rate if higher than this critical level tends to suppress the (positive) strategic and the cost effects, but enhances the (negative) licensing-revenue effect, leading to $\pi^*(\theta^*=0)>\pi^*(\theta^*=\overline{\theta})$. It implies that the foreign firm would adopt the most inferior technology, if the tariff is higher than $\hat{t}$. We get the following proposition from the above discussions:

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Proposition 1. The foreign licensor firm adopts the most inferior (superior) technology, i.e., $\theta = 0$ ($\theta = \overline{\theta}$) for its own production if the tariff rate is higher (lower) than a threshold value, i.e., $t > \hat{t}$ ($t < \hat{t}$).

The intuition of the proposition is as follows. Other things being equal, a low tariff implies a high output level by the foreign licensor firm. To save on its production cost, the licensor firm should choose the most superior technology. By contrast, if the tariff rate is high, the output of the foreign firm is low and the gain from a superior technology is small. Under such a circumstance, the foreign firm should choose the most inferior technology, yielding its market share to the domestic firm and then using the two-part tariff licensing contract to extract the rent accruing to the domestic firm.

The above finding is similar to that in Kimmel (1992) and Zhao (2001). They investigate the effects of cost reduction on the industry profit and show that a rise in the marginal cost of an inefficient firm increases the industry profit if the marginal cost difference between the firms is sufficiently large. In our model, the objective of the foreign firm in the first two stages of the game is to maximize the industry profit which is equivalent to its own profit plus the licensing revenue. If the tariff rate is high, the marginal cost difference between the firms is also high. The inefficient foreign firm has an incentive to adopt the most inferior technology, as it results in a higher industry profit.

3. Welfare implications

In this section, we compare social welfare of the domestic country (SW) when the foreign firm chooses the most superior and when it chooses the most inferior technology. The domestic social welfare is defined as the sum of consumer surplus, the profit of the domestic firm, and tariff revenue, i.e., $SW = CS(Q(r(\theta),\theta)) + \pi(r(\theta),\theta) + tq^*(r(\theta),\theta)$. First of all, by (6), the profit of the domestic firm should remain unchanged after licensing, i.e., π^N. The effect of the foreign firm's technology on the profit of the domestic firm is derivable as follows:

$$\frac{d\pi^N}{d\theta} = p' q^*_\theta q^N < 0. \tag{13}$$

Moreover, the effect of the foreign firm's technology on the tariff revenue is derivable as follows:

$$\frac{dTR}{d\theta} = t\left(q^*_r r_\theta + q^*_\theta\right) > 0. \tag{14}$$

If the foreign firm adopts a superior technology, it lowers its marginal cost, which increases its output and the tariff revenue. Finally, we can derive the effect on consumer surplus as follows:

$$\begin{aligned} \frac{dCS}{d\theta} &= -p' Q[Q_\theta + Q_r r_\theta] \\ &= -p' Q\left[\frac{-1}{3p'} + \frac{5}{6p'}\right] = \frac{-Q}{2} < 0. \end{aligned} \tag{15}$$

It shows that consumer surplus decreases with the foreign firm's technology level. An increase in θ generates two effects on output. The first one is captured by Q_θ. An increase in θ lowers the cost of the foreign firm, resulting in a higher market output. The second effect is captured by $Q_r r_\theta$, showing that an increase in θ makes the foreign firm more competitive in the output market, giving it an incentive to charge a higher royalty which raises the effective marginal cost of the domestic firm and leads to a lower market output. As the second effect dominates the first effect, both the market output and consumer surplus decrease with the foreign firm's technology. Furthermore, it is straightforward to show that $\frac{dCS}{d\theta} = -\frac{dCS}{dt}$, implying that consumer surplus increases with the tariff. The intuition for the effect can be similarly derived.

Based on the above discussions, we can arrive at the following proposition.

Proposition 2. With a linear demand, consumer surplus necessarily increases with the tariff rate. It implies that trade liberalization necessarily hurts consumer surplus.

In the trade literature, it is often found that trade liberalization encourages trade volume and is beneficial to consumers. In our model, the finding is opposite. A lower tariff makes the foreign firm more competitive in the domestic market which gives it an incentive to charge a higher royalty rate which raises the marginal cost of the domestic firm and lowers the market output and thus consumer surplus.

Our result is also related to Kabiraj and Marjit (2003) and Mukherjee and Pennings (2006). They show that a government can use a trade protection policy to induce a foreign firm to license its superior technologies to a domestic firm. In their papers, the foreign firm's technology is assumed to be given and does not vary with the domestic trade policy. In our model, it is assumed that the technology of the foreign firm is endogenously determined. If the tariff is high, the foreign firm tends to adopt the most inferior technology for its own production. From Proposition 1, we know that the foreign licensor firm adopts the most superior technology for its own production if the tariff rate is low (i.e., $t < \hat{t}$). The corresponding social welfare is defined as $SW(\theta^* = \overline{\theta})$. On

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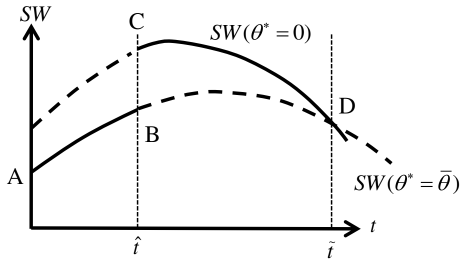

Fig. 1. Social welfare and technology.

the other hand, if the tariff is high (i.e., $t \geq \hat{t}$) and the foreign firm adopts the most inferior technology, the social welfare is defined as $SW(\theta^*=0)$. By assuming $p = a-(q+q^*)$, we can derive the social welfare difference as follows[11]:

$$\begin{aligned}\Delta SW &= SW(\theta^*=0) - SW(\theta^*=\bar{\theta}) \\ &= \frac{\bar{\theta}(34a-34c-74t+19\bar{\theta})}{72} > 0 \text{ if } t < \tilde{t} = \frac{(34a-34c+19\bar{\theta})}{74}.\end{aligned} \tag{16}$$

It shows that social welfare is higher under the most inferior technology than the most superior technology of the foreign firm if the tariff rate is not too high (i.e., $t < \tilde{t}$). The social welfare curve with respect to tariff is illustrated in Fig. 1. According to the figure, for a low tariff, the foreign firm chooses the most superior technology and the corresponding social welfare curve is AB. If the tariff rate is higher than $\hat{t}$, the foreign firm chooses the most inferior technology and the social welfare curve shifts upward to CD.[12] The adoption of the most inferior technology improves the social welfare of the domestic country.

We now examine how the adoption of the most inferior technology affects social welfare of the foreign country. It is assumed that the foreign firm does not serve its own market. Hence, social welfare of the foreign country is defined as the profit of the foreign firm. If the tariff rate is high (i.e., $t > \hat{t}$), the foreign firm should adopt the most inferior technology and the social welfare of the foreign country is higher under the most inferior technology than any other technologies.

Based on the above discussions, we can establish the following proposition.

Proposition 3. Assume the tariff rate is high (i.e., $t > \hat{t}$) such that the foreign firm adopts the most inferior technology. This technology adoption definitely raises the welfare of the foreign country. But its effect on the domestic welfare is ambiguous, depending on the value of the tariff being higher or lower than $\tilde{t}$.

4. Conclusions

Over the past two decades, technology licensing has received considerable attention and has been studied extensively. However, the literature on technology licensing did not discuss how the technology adoption of the licensor firm is being affected.

The key innovation of the paper is that there are cases in which the foreign licensor firm adopts an inferior technology for its own production when it is determined to license its most advanced technology to its competitor. This inferior technology adopted by the foreign firm increases consumer surplus and welfare of the licensee firm's country.

Whether the foreign licensor firm will adopt an inferior technology or not depends on the tariff rate of the domestic country. When the tariff is high, the foreign licensor firm adopts the most inferior technology for its own production but licenses the most superior technology to its rival. This arrangement turns out to be Pareto-improving as it increases not only the social welfare of the foreign country but also that of the domestic country.

Another interesting finding is that trade liberalization may hurt consumer surplus. This occurs because a lower tariff makes the foreign licensor firm more competitive in the output market, giving it an incentive to raise the royalty rate to alleviate competition from the rival licensee firm. This high royalty reduces the market output, making consumer worse off.

Our model can be extended in several ways. First, we have assumed that the foreign licensor firm has all the bargaining power and can extract the entire licensing rent from the licensee firm. However, this may not be the case in reality. If we consider the other extreme case where the foreign firm has no bargaining power at all (i.e., the technology can fully and freely spillover), thus receiving no licensing rent, the foreign firm does not adopt the most inferior technology since the inferior technology reduces its profit from the output market. Hence, our result holds if the foreign firm has significant bargaining power.

Second, we have assumed the foreign licensor firm employs a two-part tariff contract. An interesting question naturally arises. Should the foreign firm still choose the most inferior technology if the licensing contract is composed of only a per-unit royalty or a fixed fee? It is found that our result on the optimal technology is robust under fixed-fee licensing. The foreign firm should still

[11] The critical tariff rate at which the foreign firm takes the most inferior technology is derivable as follows: $t = (26a-26c-31\bar{\theta})/82$. Moreover, the optimal two-part tariffs are $r = (a-5t-c+5\theta-4\bar{\theta})/2$, $F = (5t+c+6\bar{\theta}-5\theta-a)(a+7t-7\theta-c+6\bar{\theta})/9$.

[12] By comparing t and $\tilde{t}$, we obtain that $\tilde{t}-t = (216a-216c+963\bar{\theta})/1517 > 0$, implying that the range of CD is non-empty. It implies that the adoption of the most inferior technology by the foreign licensor firm may raise the welfare of the domestic country.

adopt the inferior technology when the tariff rate is high enough. The intuition behind this result is as follows. Since under a pure fixed fee licensing, the foreign licensor cannot use royalty to alleviate competition from the rival licensee firm, the foreign firm is better off by choosing the most inferior technology, thus increasing the industry profit, and then extracting the gain from a higher industry profit via the fixed fee. By contrast, if the foreign firm can charge only a royalty, it can use the royalty to alleviate competition from the licensee firm, leaving it no incentive to choose the most inferior technology.

Finally, our paper deals with only process innovation. However, empirical evidences reveal that licensing of product innovation is very common. It is of some interest to apply our model to the case of product innovation and compare our results to the literature on licensing under vertical product innovation such as Nabin, Nguyen, and Sgro (2011). This is reserved for our future research.

Acknowledgements

We are grateful for the helpful comments from two anonymous referees. This paper was presented at the Conference on 'Economic Linkages through International Trade, Investment, Migration and Tourism' on May 30–31, 2015, Hong Kong. The conference, organized by Chu Hai College of Higher Education, is supported by the IIDS Grant (Project No: UGC/IIDS13/B01/14) from the Hong Kong Research Grant Council.

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