Trade Liberalization, Technology Transfer and Endogenous R&D

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Abstract

It is generally believed that trade liberalization can impede technology transfers from aboard. By considering R&D behavior of the foreign firm, this paper shows contrarily that trade liberalization has a positive effect on the foreign firm's R&D, resulting in a better technology to be transferred to the domestic firm and enhancing both the domestic and the world welfare. This result holds for trade liberalization in terms of not only tariff barriers but also non-tariff barriers such as quotas. By comparing the technology transfers between the tariff and the quota regimes, we also find that when the trade barrier is low (high), a tariff policy can help the domestic country acquire superior (inferior) technology than the equivalent quota policy. In terms of social welfare effects, we find that if the tariff rate is low, the domestic welfare levels are equal under the two regimes; if the tariff rate is high tariffs incur a higher domestic welfare. Finally, a ban on technology export by the foreign country may surprisingly induce the foreign firm to invest more on its R&D.

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1. INTRODUCTION

International technology transfer has been burgeoning in the world.[1] Many firms in developing countries, such as China, endeavor to catch up the technology ladder via technology transfer from developed countries. It has been argued that a government can use a trade protection policy to induce foreign firms to transfer their superior technology to domestic firms (Kabiraj and Marjit, 2003; Mukherjee and Pennings, 2006). By employing an international duopoly Cournot model and treating the technology level as an endogenous variable, we shall show that a more superior technology will be transferred from aboard as trade barriers *decrease*. That is to say, a less restrictive trade policy can help the domestic firm acquire more advanced technology, a result which has not been documented in the literature.

There is an extensive body of literature that investigates the relationship between trade policies and firm's technology choice. For example, Reitzes (1991) shows that quotas and tariffs often result in opposite effects on the protected firm's R&D investments. Miyagiwa and Ohno (1995) find that a permanent tariff accelerates the protected firm's technology adoption, while a permanent quota procrastinates the protected firm's adoption unless the quota is highly restrictive. Furthermore, Chiou *et al.* (2006) assume there is a foreign firm competing with a domestic firm in the domestic market and compare the effects of a tariffs and the equivalent quota on the domestic firm's technology choice. They find that the technology level is necessarily higher under a tariff than the equivalent quota if the two firms compete in Cournot fashion but the ranking is ambiguous if the two firms compete in Bertrand fashion. These papers all assume the technology of the foreign firm to be exogenously given,

[1] See Rostoker (1984), Kamien (1992) and Saggi (2002) for detailed reviews.

and fail to capture the effect of trade protection on the foreign firm's R&D which in turn affects the technology level to be transferred to the protected firm.

Our paper is also closely related to the literature on trade policies and technology licensing, such as Kabiraj and Marjit (2003), Mukherjee and Pennings (2006) and Horiuchi and Ishikawa (2007). In particular, Kabiraj and Marjit (2003) consider a duopoly model where a foreign firm and a domestic firm compete in the domestic country and show that tariff may induce a technology transfer from the foreign firm to the domestic firm thereby making consumers in the domestic country better off. Our model differs from theirs in several ways. First, they treat the foreign technology as an exogenously binary whereas we allow the foreign firm to choose endogenously its R&D. Second, they consider only tariff barriers, but we study both tariff and non-tariff barriers and compare their effects on technology transfers. Finally, they assume the foreign firm adopts fixed-fee licensing whereas we assume it chooses royalty as the means of licensing. Moreover, Mukherjee and Pennings (2006) set up a model in which the foreign monopolist can license its superior technology to either another foreign firm or to a domestic firm. They explore how the host government uses a tariff policy to affect the licensing decision and the domestic welfare. Both papers suggest that an increase in tariff encourages international technology transfer. Moreover, Horiuchi and Ishikawa (2007) show that an increase or a decrease in tariff on a final good may induce technology transfer in its intermediate good. However, these papers have overlooked the fact that trade policies may alter the R&D behavior of the foreign firm and the technology level to be transferred to the domestic firm. By treating the R&D of the foreign firm to be endogenously determined, we shall show that trade liberalization can in fact help the domestic firm acquire a better technology as it induces the foreign firm to invest more on its R&D.

The main findings of this paper are as follows. Contrary to the findings in Kabiraj and Marjit (2003) and Mukherjee and Pennings (2006), tariffs have a negative effect on technology transfer. A higher tariff tends to impede the foreign firm's R&D investment, causing the foreign firm to license an inferior technology to the domestic firm. Quotas have a similar effect. By comparing the technology transfers between a tariff and the equivalent quota, we find that the licensed technology is inferior (superior) under a tariff than the equivalent quota if the tariff is high (low).

Many developed countries impose a tight control on its technology export. In this paper, we have also examined the effect of such a policy on the foreign firm's R&D. It is found with surprise that if the R&D efficiency of the foreign firm is high, a ban on technology export increases the foreign firm's R&D investment.

The remainder of the paper proceeds as follows. Section 2 sets out the basic model. Section 3 examines the effect of trade liberalization on the technology level transferred from aboard. Section 4 explores whether a quota or a tariff is more efficient in inducing superior technology transfer. Section 5 investigates the effect of a technology export control on the R&D of the foreign firm. Section 6 concludes the paper.

2. THE BASIC MODEL

Consider a domestic market with a domestic firm and a foreign firm producing a homogeneous good and competing in Cournot fashion. The foreign firm can improve its technology to reduce its marginal cost via R&D and the R&D cost function is defined as $V(x)$ with $V'(x) > 0,\ V''(x) > 0$, where "primes" refer to derivatives. This R&D investment lowers the foreign firm's marginal cost by x. To ensure licensing to take place, the technology gap between the two firms is assumed to be non-drastic throughout this paper. Also, when licensing its technology, the foreign firm charges a per unit royalty rate, r. Thus, after licensing, the marginal cost of the foreign firm is $c-x$ whereas that of the domestic firm is $c-x+r$. Moreover, the inverse demand function for the good takes the following implicit form: $p=p\left(q+q^{*}\right)$ with $p'<0$ and $p''=0$ where q and q^{*} are respectively the outputs of the domestic firm and the foreign firm, and an asterisk is added to variables associated with the foreign firm. We further assume that the domestic government imposes either a quota or a specific tariff on imports from the foreign firm.

The game in question consists of three stages. In the first stage, the foreign firm, given the trade policy of the domestic government, determines its optimal technology level. In the second stage, taking the technology level as given, the foreign firm licenses its superior technology to the domestic firm through a royalty contract. In the third stage, the two firms compete in quantity in the domestic market. Before the first stage of the game, the domestic government can impose a trade policy, being an import tariff or an import quota. We shall examine how trade protection affects the R&D of the foreign firm and the technology acquired by the domestic firm. This gives rise to a subgame perfect equilibrium in the three-stage game. We shall solve this equilibrium by the standard backward induction.

3. TRADE LIBREALIZATION AND TECHNOLOGY TRANSFER

In this section, we examine the impact of trade liberalization on the technology level transferred from the foreign firm when tariff is taken as the protection policy. To solve the subgame perfect equilibrium, let us begin with the third-stage problem. The profit functions of the domestic firm and the foreign firm can be specified respectively as follows.

$$\pi(q,q^{*})=(P-c+x)q-rq\,, \qquad (1)$$

$$\pi^*(q^*, q) = (P - c + x - t)q^* + rq - V(x).\ , \tag{2}$$

where t is the specific tariff imposed by the domestic government.

By differentiating (1) with respect to q and (2) with respect to q^*, the first-order conditions for profit maximization in the third-stage game are derivable as follows:

$$\frac{d\pi}{dq} = P - c + x - r + P'q = 0\,, \tag{3}$$

$$\frac{d\pi^*}{dq^*} = P - c + x - t + P'q^* = 0. \tag{4}$$

The second-order conditions and the stability condition are all satisfied as $d^2\pi/dq^2 = 2P' < 0$, $d^2\pi^*/dq^{*2} = 2P' < 0$ and $|H| = 3(P')^2 > 0$. From (3) and (4), we can derive the following comparative static effects:

$$\frac{dq}{dt} = \frac{-1}{3P'}, \quad \frac{dq}{dr} = \frac{2}{3P'}, \quad \text{and} \quad \frac{dq}{dx} = \frac{-1}{3P'}; \tag{5}$$

$$\frac{dq^*}{dt} = \frac{2}{3P'}, \quad \frac{dq^*}{dr} = \frac{-1}{3P'}, \quad \text{and} \quad \frac{dq^*}{dx} = \frac{-1}{3P'}. \tag{6}$$

These equations indicate that the domestic firm's output increases with tariff and the foreign firm's technology level but decreases with the royalty rate while the foreign firm's output increases with the royalty rate and its technology level but decreases with the tariff.

We now move to the second-stage game to derive the optimal royalty rate. By substituting $q(r,x)$ and $q^*(r,x)$ derived from (3) and (4) into (1), we can rewrite the profit function of the foreign licensor firm as follows:

$$\max_r \pi^*(q(r), q^*(r), r; x) = (P - c + x - t)q^* + rq - V(x)\,, \tag{7}$$

$$\text{s.t.} \quad (P(r,x) - c - x + r)q(r,x) \geq (P(x) - c)q(x)\,.$$

The above equation indicates that the foreign firm's optimal royalty rate is subject to an incentive constraint such that the domestic firm makes no less profits after licensing, so as to ensure the licensing contract to be accepted by the domestic firm. By differentiating (7) with respect to r and utilizing (3) and (4), we can derive the first-order condition for profit maximization as follows:

$$\frac{d\pi^*}{dr} = \frac{\partial \pi^*}{\partial q}\frac{\partial q}{\partial r} + \frac{\partial \pi^*}{\partial r} = (P'q^* + r)\frac{\partial q}{\partial r} + q = (P'q + t)\frac{\partial q}{\partial r} + q \begin{cases} > 0 \\ = 0 \end{cases} \text{if} \begin{array}{l} t < \hat{t} \\ t \geq \hat{t} \end{array} \quad (8)$$

It is straightforward to show that $d\pi^*/dr > 0$ and the optimal royalty rate has the corner solution $r = x$ if $t < \hat{t}$, where $\hat{t} = -5P'q/2 \geq 0$. On the other hand, if $t \geq \hat{t}$, the optimal royalty rate has an interior solution and is derivable as $r = -P'(q^* + 3q/2)$ In sum, the optimal royalty rate can take either a corner or an interior solution, depending on the magnitude of the tariff:

$$r = \begin{cases} x \\ -P'(q^* + \frac{3}{2}q) \end{cases} \text{if} \begin{array}{l} t < \hat{t} \\ t \geq \hat{t} \end{array}, \quad (9)$$

where $\hat{t} = -5P'q/2 \geq 0$. If the tariff is high, the foreign is relatively inefficient in competing with the domestic firm in the domestic market. It gives the foreign firm an incentive to charge a low royalty so as to expand the sales of the domestic firm and extract the rent via the royalty. Utilizing (5) and (6), we can also derive the comparative static effect as follows:

$$\frac{\partial r}{\partial x} = \begin{cases} 1 \\ 1/2 \end{cases} \text{if} \begin{array}{l} t < \hat{t} \\ t \geq \hat{t} \end{array}. \quad (10)$$

It shows that for a low tariff, the foreign licensor firm's optimal royalty rate is exactly equal to the cost-saving of the domestic firm from the licensed technology, leaving the profit of the domestic (licensee) firm unchanged. However, if the tariff is high, the foreign (licensor) firm can only extract the rent partially and the domestic firm can still enjoy some rent from the new technology.

Given these properties, we can specify the profit function of the foreign firm for the first-stage game as follows:

$$\max_x \pi^*(q(r(x),x), q^*(r(x),x), r(x), x) = (P-c+x-t)q^* + rq - V(x) . \qquad (11)$$

The optimal R&D of the foreign firm can be derived by differentiating (11) with respect to x which leads to the following first-order condition for profit maximization:

$$\frac{d\pi^*}{dx} = \frac{\partial \pi^*}{\partial q}\frac{dq}{dx} + \frac{\partial \pi^*}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial \pi^*}{\partial x} = \underbrace{(P'q^*)\frac{dq}{dx}}_{\text{strategic effect}} + \underbrace{q^*}_{\text{output effect}} + \underbrace{r\frac{dq}{dx} + q\frac{\partial r}{\partial x}}_{\text{licensing effect}} \underbrace{-V'}_{\text{cost effect}} = 0 \quad (12)$$

The second-order condition requires that $d^2\pi^*/dx^2 < 0$ which is satisfied given the linear demand and the increasing R&D marginal cost.

Equation (12) shows that there are four terms jointly determining the foreign firm's optimal technology level. The first term is called the strategic effect which is positive. It indicates a greater x (i.e., better technology) lowers the output of the domestic firm, increasing the profit of the foreign firm. The second term is called the output effect, which captures the cost saving from the existing output and is also positive. The third term is called the licensing revenue effect. The sign of this effect is ambiguous as rq is concave in x. The last term which is negative, represents the R&D cost effect.

By substituting $dq/dx = (\partial q/\partial r)(\partial r/\partial x) + \partial q/\partial x = \begin{cases} 1/3P' & \text{if} \quad t < \hat{t} \\ 0 & \quad\quad t \geq \hat{t} \end{cases}$ (by (5) and (10)) into (12) and making use of (10), we obtain:

$$\frac{d\pi^*}{dx} = \begin{cases} (P'q^* + x)(\frac{1}{3P'}) + q^* + q - V' = 0 & \text{if} \quad t < \hat{t} \\ q^* + \frac{q}{2} - V' = 0 & \quad\quad t \geq \hat{t} \end{cases} \qquad (13)$$

It shows that the optimal technology of the foreign firm depends on the tariff rate. By totally differentiating the above equation, we can derive the effect of t on x as follows.

$$\frac{dx}{dt} = \begin{cases} \frac{5}{2+9P'V''} < 0 & \text{if} \quad t < \hat{t} \\ \frac{1}{1+2P'V''} < 0 & \quad\quad t \geq \hat{t} \end{cases},$$

These effects are robust only if the second-order condition is satisfied which requires $V'' > -1/2P'$.

We can use Figure 1 to illustrate the economic meaning of (13). Two notes are warranted here. First, the foreign firm's R&D is high (low) when the tariff is lower (higher) than the critical level. At the critical tariff rate, the optimal royalty rate is discontinuous, causing a drop in the R&D. As shown in (9), if the tariff is higher than the critical level, the foreign firm charges a full royalty and extracts the entire rent of the domestic firm from the new technology, giving the foreign firm an incentive to engage in more R&D. Contrarily, if the tariff is higher than the critical level, the foreign can extract only a partial rent from the domestic firm, causing the foreign to engage in less R&D. Second, in either case, the R&D is negatively related to the tariff rate. It implies that a less restrictive tariff definitely induces the foreign firm to invest more on R&D and to transfer a higher level of technology to the domestic firm. Thus, we can arrive at the following lemma.

Proposition 1: The lower the tariff, the better is the technology to be transferred by the foreign firm.

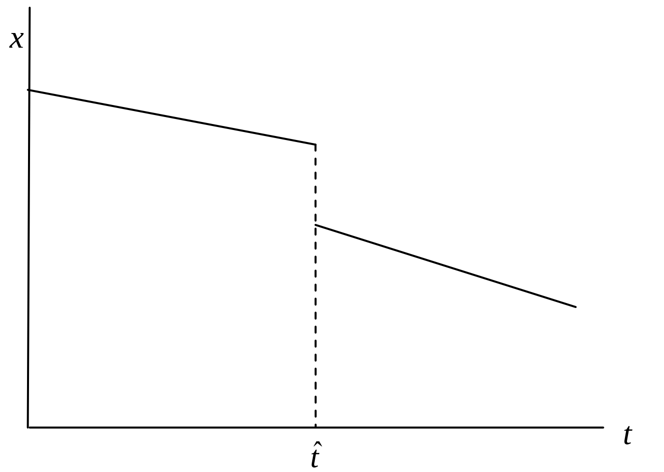

Figure 1. Tariffs and Optimal R&D

4. INTERNATIONAL TECHNOLOGY TRANSFER UNDER QUOTAS

Instead of tariffs, the host government can also take non-tariff barriers as its protection policy. Among non-tariff barriers, import quota is most popular. In this section, we examine how a change in import quota affects the R&D of the foreign firm and the following international technology transfer.

In this quota regime, the objective profit functions for the domestic firm and the foreign firm become as follows:

$$\pi(q) = (P - c + x)q - rq\,, \tag{14}$$

$$\pi^* = (P - c + x)\bar{q}^* + rq - V(x)\,. \tag{15}$$

where $\bar{q}*$ is the (effective) quota set by the home government.[2]

As the foreign firm's output is subject to the quota constraint, the domestic firm behaves as a Stackelberg leader in the home market. By differentiating (14) with respect to q, we can derive the first-order condition for profit maximization for the foreign firm as follows.

$$\frac{d\pi}{dq} = P - c + x - r + P'q = 0\,. \tag{16}$$

The second-order condition is satisfied as $\pi_{qq} < 0$. Moreover, by totally differentiating(16), we can derive the following comparative static effects:

$$\frac{dq}{dr} = \frac{1}{2P'}, \quad \frac{dq}{dx} = \frac{-1}{2P'}, \quad \frac{dq}{d\bar{q}^*} = \frac{-1}{2}\,. \tag{17}$$

Expressions in (17) indicate that an increase in the import quota or the royalty rate has negative effects whereas an increase in the level of the technology has a positive effect on the domestic firm's output. Moreover, different from that in (5) where the effects of the royalty rate or the R&D on the domestic firm's output are

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[2] A quota is effective if the market price is higher than the marginal cost of the exporting firm. We shall assume this to be the case throughout the analysis.

opposite in sign but at different magnitudes, they now have the same magnitude.

By substituting $q(r,x)$ derived from (16) into (15), we can rewrite the profit function of the foreign licensor firm as follows:

$$\max_r \pi^*(q(r),r) = (P-c+x)\overline{q}^* + rq - V(x)\,, \tag{18}$$

$$\text{s.t.}\quad (P(r,x)-c-x+r)q(r,x) \geq (P(x)-c)q(x)\,. \tag{19}$$

The constraint represents the licensee firm's incentive constraint, implying that the domestic firm is not worse off after licensing. By totally differentiating (18) with respect to r and utilizing (16), we can derive the first-order condition for profit maximization as follows:

$$\frac{d\pi^*}{dr} = \frac{\partial \pi^*}{\partial q}\frac{\partial q}{\partial r} + \frac{\partial \pi^*}{\partial r} = (P'\overline{q}^* + r)\frac{\partial q}{\partial r} + q = q^*/2 - (2P-2c+2x-3r)/2P' > 0\,. \tag{20}$$

The sign of (20) is positive as $r \leq x < P-c$ by (19) and the innovation is assumed to be non-drastic.[3] Equation (20) implies that, the foreign firm's optimal royalty rate is the rate that extracts all the increased profits of the domestic firm, i.e., $r = x$. Utilizing this property, we can rewrite the profit function of the foreign firm for the first-stage game as follows:

$$\max_x \pi^*(q(r(x),x),r(x),x) = (P-c+x)\overline{q}^* + rq - V(x)\,. \tag{21}$$

By totally differentiating (21) with respect to x, we can derive the optimal royalty rate under the quota regime from the following first-order condition for profit maximization:

$$\frac{d\pi^*}{dx} = \frac{\partial \pi^*}{\partial q}\frac{dq}{dx} + \frac{\partial \pi^*}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial \pi^*}{\partial x}$$

$$= \underbrace{(P'\overline{q}^*)(\frac{\partial q}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial q}{\partial x})}_{\text{strategic effect}} + \underbrace{\overline{q}^*}_{\text{output effect}} + \underbrace{r(\frac{\partial q}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial q}{\partial x}) + q\frac{\partial r}{\partial x}}_{\text{licensing effect}} \underbrace{-V'}_{\text{cost effect}}$$

$$= \overline{q}^* + q - V' = 0\,. \tag{22}$$

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[3] Given the innovation to be non-drastic, the domestic firm's output is positive which requires $x < P-c$. In addition, the licensee firm accepts the licensing contract only if $r \leq x$.

The second-order conditions is satisfied as $d^2\pi / dx^2 = -V'' < 0$. Given r being equal to x, the domestic firm's output is unchanged after licensing. As a result, the strategic effect vanishes and the foreign firm's marginal revenue from better technology is now equal to its saved production cost. The optimal technology is determined when this marginal revenue is equal to the marginal cost. Furthermore, by totally differentiating (22), we can derive the comparative static effect of quota on the optimal R&D as follows:

$$\frac{dx}{d\overline{q}^*} = \frac{1}{2V''} > 0, \tag{23}$$

A less restrictive quota policy encourages the foreign firm to choose a higher technology and license this higher technology to the domestic firm. The intuition is as follows. An increase in quota increases the total market output by (17) which raises the marginal revenue of the R&D investment and induces the foreign firm engage in more R&D. Based on the finding, we can construct the second Proposition as follows.

Proposition 2. The higher the quota, the better is the transferred technology.

Propositions 1 and 2 have shown that either a lower tariff or a higher quota can induce a better transferred technology. It implies that with an endogenous R&D by the foreign firm, trade liberalization, rather than trade protection, results in better technology to be transferred from the foreign firm to the domestic firm. This result is contrary to the finding of Kabiraj and Marjit (2003). They show that a tariff, if *high* enough, can induce international technology transfer. The difference arises from the assumption on the foreign firm's technology level. In their paper, the foreign technology is assume to be given and does not vary with the domestic trade policy. In our model, it is assumed that the R&D of the foreign firm is endogenously determined.

A higher trade protection, from either a tariff or a non-tariff barrier, induces the foreign firm to invest less on its R&D and results in a lower level of the transferred technology.

We have investigated the optimal technology levels of the foreign firm under the tariff and the quota regimes. In what follows, we shall compare which trade policy can induce a better technology to be transferred from the foreign firm to the domestic firm.

By evaluating (13) at the technology level derived from (22) and utilizing the condition of equivalent import volume under the two regimes, i.e. $\bar{q}^* = q^*(t)$, we can obtain:

$$\left.\frac{d\pi^*(\bar{q}^*)}{dx}\right|_{\bar{q}^*=q^*(t),\bar{x}=\hat{x}} = \begin{cases} q^*(t) + \dfrac{x}{3P'} > 0 & \text{if} \quad t < \hat{t} \\ -q(t)/2 < 0 & \phantom{\text{if}} \quad t \geq \hat{t} \end{cases}.$$

It shows that the technology difference between tariffs and quotas depends on the level of trade protection. For a low (high) tariff, the output of the foreign firm is large (small). Under such a circumstance, a tariff (the equivalent quota) can induce a better technology to be transferred from the foreign firm. Thus, we can establish the following proposition.

Proposition 3. For a low (high) tariff, a tariff policy is more (less) effective in acquiring better foreign technology than the equivalent quota policy.

Note that when the trade barrier is low, the foreign licensor firm charges $r = x$, and the marginal cost of the domestic firm remains at c under both regimes. This together with the assumption of the same import volume leads to the same total output and the same domestic welfare under the two regimes if the tariff revenue is set equal to the quota rent.[4] In addition, Proposition 3 implies that if the trade barrier is low, a tariff policy is superior to the equivalent quota policy in terms of the licensed technology. As a higher level of the licensed technology leads to a higher foreign profit and no worse domestic profit, we can conclude that if the trade barrier is low, a tariff policy leads to higher foreign and world welfare than the equivalent quota policy. On the other hand, if the trade barrier is high, the royalty rate is smaller than the marginal cost reduction of the licensee firm under the tariff regime but they are equal under the quota regime. It implies that the domestic firm can enjoy a lower marginal cost and a higher profit under the tariff regime. Moreover, domestic consumer surplus and the world welfare are both higher under the tariff regime as the total output is higher. If we further set the tariff revenue equal to the quota rent, the domestic welfare is also higher under the tariff regime. Based on the above discussions, we can establish the following proposition.

Proposition 4. If the trade barrier is low and the quota rent is set equal to the tariff revenue, the domestic welfares are the same under the tariff and the quota regimes but the foreign and the world welfares are higher under the tariff regime. On the other hand, if the trade barrier is high, the domestic welfare and the world welfare are both higher but the foreign welfare if lower under the tariff regime.

WTO has long been pursuing trade liberalization and tarrification. According to our findings, tariffication (i.e., converting non-tariff barriers into tariff barriers) should be pursued as it leads to higher world welfare, whether trade barriers are high or low.

[4] The domestic welfare consists of the domestic firm's profit and the domestic consumer surplus whilst the world welfare comprises the domestic welfare and the foreign firm's profit.

5. EXPROT TECHNOLOGY CONTROL

It is generally believed that licensing gives the licensor firm an extra channel to make profits and thus has a positive effect on its R&D. Based on this argument, a firm's R&D should decline if its government imposes a ban on technology transfer. In this section, we shall use the basic model to show that this argument is misleading if the foreign firm is efficient in its R&D.

When technology transfer is banned, there is no licensing and the game degenerates to two stages. The foreign firm determines its optimal R&D in the first stage, and the two firms compete in the output market in the second stage. The output game is the same as before and shall not be repeated here. But we need to re-derive the equilibrium for the first-stage game. With no licensing, the first-order condition to derive the optimal R&D of the foreign firm becomes:

$$\frac{d\pi^*}{dx} = \underbrace{(p'q^*)\frac{\partial q}{\partial x}}_{\text{strategic effect}} + \underbrace{q^*}_{\text{output effect}} - \underbrace{V'(x)}_{\text{cost effect}} = \frac{4q^*}{3} - V'(x) = 0, \qquad (24)$$

The difference between (24) and (12) is that there is no licensing effect in the above equation as technology export is banned now.

We can compare the foreign firm's optimal R&D levels with and without the ban on technology export. Note that if there is no such a ban, the optimal royalty rate is equal to x when $t < \hat{t}$ by (9).[5] Hence, the outputs of the two firms are the same with and without the ban. Evaluating (24) at the optimal R&D level derived from (12) and utilizing the property of $r = x$, we can obtain:

$$\left.\frac{d\pi^*(\bar{q}^*)}{dx}\right|_{\hat{x}=x} = -q - \frac{r}{3P'} \begin{matrix} > 0 \\ = 0 \\ < 0 \end{matrix} \quad \text{if} \quad \begin{matrix} V' < \hat{V}' \\ V' = \hat{V}'. \\ V' > \hat{V}' \end{matrix} \qquad (24)$$

[5] We shall pursue only this case. The result for the other case of $t > \hat{t}$ is similar to the current one and can be similarly derived.

The sign of (24) is ambiguous. It is positive if the foreign firm's R&D efficiency is high. Given this result, we can construct the following proposition.

Proposition 5. When the R&D efficiency of the foreign firm is high, a ban on technology export has a positive effect on the foreign firm's technology development.

The intuition of this proposition is as follows. When technology export is not banned, the foreign firm can earn revenues via two channels --- sales of its output and technology licensing. The revenue from the former is higher, if the foreign firm has higher R&D efficiency as it leads to a higher technology and a lower marginal cost. But this is not the case for the licensing revenue as by definition its magnitude depends on the output of the "domestic" firm. If technology export is banned, the foreign firm does not need to take into account its effect on the output of the domestic firm while making its technology choice and should choose a better technology.

6. CONCLUSIONS

It is well known in the trade literature that trade protection can induce international technology transfer via licensing. It implies that a country can use trade protection to help its firms to acquire better technology from a foreign firm. This paper argues that this result does not hold if the R&D of the foreign licensor firm is determined endogenously. We have shown that trade protection has a negative effect on the foreign firm's R&D and hence on its technology transferred to the home country. It implies that a technology importing country should liberalize its trade protection if it intends to import better technology.

Trade liberalization can encourage the foreign firm to choose better technology to be licensed to the domestic firm. This better technology can lower the production cost of the domestic and the foreign firms and also the price in the domestic country, leading to high domestic, foreign and world welfare. This result can be used to justify trade liberalization policies advocated by the WTO.

We have also compared the effects on international technology transfer between a tariff and the equivalent quota policy and the resulting welfare implications. It is found that when the trade barrier is low, a tariff policy is better than the equivalent quota policy in terms of the level of transferred technology. The opposite holds if the trade barrier is large. The domestic welfare is indifferent under the two regimes if the trade barrier is low but it is higher under the tariff regime if the trade barrier is high. Moreover, the world welfare is definitely higher under a tariff policy irrespective of the magnitude of the trade barrier. This result echoes the tariffication policy proposed by WTO.

Finally, we have investigated how the R&D of the foreign firm is affected by the foreign government's ban on technology export. We have found that a ban on technology export entails a positive (negative) effect on the technology of the foreign firm if its R&D efficiency is high (low).

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