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Iida, Takeshi

Takeuchi, Kenji

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Environmental Technology Transfer via Free Trade

Takeshi Iida[a] and Kenji Takeuchi[a*]

a Graduate School of Economics,
Kobe University, Hyogo, 657-8501, Japan

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Abstract

This paper considers a model of international duopoly with global pollution to investigate the impact of tariff policy and licensing contracts on environmental technology transfer. Our main finding is that free trade is not always preferable. When the protection of intellectual property rights (IPR) is within a certain range, there is a possibility that the total world welfare is higher under a positive tariff rate than under a zero tariff rate. This implies that the protection of IPR beyond the range is a prerequisite for the justification of free trade.

We also show how developing countries are induced to sign a licensing contract. Even if the licensing does not directly improve the competitiveness of the firm in the developing country, raising the tariff rate can increase the revenue of the country. In contrast, when there is no licensing agreement, the local government sets a lower tariff rate and diffuses the products of foreign firms, because the products of local firms are associated with pollution.

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*Corresponding author. E-mail address: takeuchi@econ.kobe-u.ac.jp

1 Introduction

Transfer of low-carbon and renewable technology to fast-growing economies is a key aspect in addressing global climate change (IPCC 2007, 218-224). Developing countries often claim that compulsory licensing, by which a government forces the holder of a patent to grant use of the technologies to the state or others, is effective for the transfer of environmental technologies. Industrialized countries, however, tend to prefer a free trade policy, where technology is indirectly transferred through the trade of commodities that are produced in their countries. From this standpoint, it is necessary to remove tariffs and other trade barriers to decrease the price of environmental technology.

A World Bank (2008) summary of applied tariffs for solar photovoltaic technology in 18 high-GHG-emitting developing countries found that except in one case, import tariffs range from 32 to 6 percent. These are much higher than the average tariffs in high-income OECD countries (4%). Tariff barriers on fluorescent lamps in these 18 countries are also high, varying from 30 to 5 percent, again with one exception. The tariff on fluorescent lamps is the highest across all clean technologies assessed.

This paper considers an international duopoly model to investigate the impact of tariff policy and licensing contracts on environmental technology transfer. Our main finding is that free trade is not always preferable to tariffs. When the protection of intellectual property rights is within a certain range, there is a possibility that the total world welfare is higher under a positive tariff rate than under a zero tariff rate.

Another contribution of this paper is to show how developing countries are induced to sign a licensing contract. Suppose a developing country can change its tariff rate after the contract. Even if the licensing does not directly improve the competitiveness of the firm in the developing country, it can increase its revenue by raising the tariff rate.

Some previous studies have examined the relationship between trade policy and environmental technology transfer. Itoh and Tawada (2003) analyse the welfare effect of trade and environmental technology transfer from a developed country to a developing country using a Ricardian general equilibrium model. In the case of local pollution, a developed country may be worse off if its technology is transferred. Takarada (2005) also studies the welfare effects of a transfer of pollution abatement technology in the absence of pollution policy, using a two-country general equilibrium model. Since the model incorporates incomplete specialization, the technology transfer may impoverish both the recipient and donor even if the pollution is trans-boundary. Hattori (2007) investigates a model with international oligopoly and trans-boundary pollution, and shows that policy and product differentiation between the donor and recipient plays a significant role in the agreement of technological transfer. The previous studies assume that the technological transfer is free of charge and focus mainly on transfer through public funding, whereas this study considers two channels for the transfer of technology of a private firm: international trade and licensing contracts. [1] We incorporate royalty fees in our model and emphasize the interaction between trading of goods and licensing of technology through the setting of tariffs.

Although the basic structure of our model is similar to those of Kabiraj and Marijit (2003) and Mukherjee and Pennings (2006), there are three important differences. First, we consider global pollution while these studies do not. Accordingly, our analysis can address the situation when technological transfer is potentially beneficial for any country from the environmental point of view. Second, our analysis incorporates intellectual property rights (IPR) as a factor having significant implications for technological transfer. One of our findings suggests that the protection of IPR is prerequisite for justifying free trade. Third, in contrast to Kabiraj and Marijit (2003), our model does not assume that the difference in production cost is a significant incentive for

[1] Popp (2008) considers public funding and private firm behaviour as sources of technological transfer. A representative example of public funding is aid from governments or non-governmental organizations in the form of official developmental assistance. Private transfer of technology can take place in three ways: trade, foreign direct investment, and license to a local firm.

technological transfer.

The remainder of this paper is organized as follows. We present an international duopoly model with pollution in Section 2. In Section 3, we investigate free trade policy and compare it with a case where the local country determines the tariff rate after the licensing activity. Section 4 extends the analysis to the case when the local government commits to a specific tariff rate. The final section provides our conclusions.

2 The model

We consider a model of duopoly with one foreign firm and one local firm. We suppose the good is homogeneous exccept for its environmental properties. The good produced by the local firm generates global external diseconomy. The foreign firm has the clean technology; therefore, its product does not adversely affect the environment. The clean technology of the foreign firm is transferable. If the technology is transferred by a licensing agreement to the local firm, its product does not cause environmental damage. We assume that the license fee is paid by royalties, although a qualitatively similar result is obtained under the assumption of a fixed fee.

First, we examine the case where there is no licensing contract. The profits of the foreign firm and local firm under a no-license situation are $\pi_e^N = pq_e - t^N q_e$ and $\pi_i^N = pq_i$, where p is the price, q_e and q_i are the quantities of the good produced by the foreign firm and local firm, and t is the tariff rate imposed on product of the foreign firm. Subscripts e and i denote the foreign firm and local firm, respectively. We assume a linear inverse demand function, $p = \alpha - q_e - q_i$. The marginal private cost of producing the good is standardized to zero. The social welfare of the foreign country is the sum of the producer surplus minus environmental damage, $SW_e^N = \pi_e - ED_e$. The social welfare of the local country is the sum of the consumer surplus, profit of the local firm and tariff revenue minus the environmental damage, that is $SW_i^N = (q_e+q_i)^2/2+\pi_i^N+t^N q_e-ED_i$.

We assume that the consumption of the home country generates global pollution and omit the consumption in the foreign country for the ease of analysis. Environmental damage for the foreign and local countries are represented as $ED_e = m_e(\beta q_i)^2$ and $ED_i = m_i(\beta q_i)^2$, respectively. One unit of consumption generates one unit of pollution. The parameters m_e and m_i are the evaluation of the environmental damage by each country, and we assume that $m_e = m_i = 1$. [2] The exogenous parameter $\beta \in (0, 1]$ represents the degree of IPR protection. If $\beta \in (0, 1)$, imperfect IPR protection exists, which means that the local firm can freely copy the technology of the foreign firm. We

[2]The parameterization of m_e and m_i should be different depending on the situation and characteristic of the environmental issue. In the case of global climate change, it seems that developed countries are more concerned than developing countries. Therefore, it would be appropriate to assume $m_e \geq m_i$. In an extreme case, where $m_e = 1$ and $m_i = 0$, the local country does not find any value in a licensing agreement.

assume that it is impossible to imitate the technology perfectly and remove the case where $\beta = 0$.

Next, we examine the case where a licensing agreement does exist. Profits of the foreign firm and local firm under the licensing contract are $\pi_e^L = pq_e - t^L q_e + rq_i$ and $\pi_i^L = pq_i - rq_i$, where r is the royalty rate. Since licensing eliminates environmental damage, the social welfare of the foreign country is equal to the producer surplus, $SW_e^L = \pi_e^L$. The social welfare of the local country is $SW_i^L = (q_e + q_i)^2/2 + \pi_i^L + t^L q_e$. The total social welfare of the world is defined as $SW_w^N = SW_e^N + SW_i^N$, $SW_w^L = SW_e^L + SW_i^L$.

3 Comparing free trade and no commitment

3.1 Free trade

We consider the case of free trade where the tariff rate is fixed at zero. A lower tariff rate can increase the export of goods with low carbon emission from developed to developing country, which can help diffuse the environmental technology embodied in it. The timing of this game is as follows. In the first stage, the foreign firm offers royalty r to the local firm. In the second stage, the local firm decides whether to accept the offer. In the final stage, the firms engage in quantity competition. The game is solved backwards.

The second stage equilibrium quantity with and without licensing become

$$q_e^{F,L} = \frac{\alpha + r}{3}, \quad q_i^{F,L} = \frac{\alpha - 2r}{3}. \tag{1}$$

$$q_e^{F,N} = q_i^{F,N} = \frac{\alpha}{3}, \tag{2}$$

From (1) and (2), we can derive a license fee $r^F = 0$ such that $q_i^{F,L} = q_i^{F,N}$. This means that the local firm has no incentive for accepting a licensing contract. Moreover, since the contract does not change the profit of the foreign firm, licensing does not occur. The equilibrium in the free trade regime is denoted as $p^F = \alpha/3, q_e^F = q_i^F = \alpha/3, \pi_e^F = \pi_i^F = \alpha^2/9, SW_e^F = \alpha^2(1-\beta^2)/9, SW_i^F = \alpha^2(3-\beta^2)/9, SW_w^F = \alpha^2(4-2\beta^2)/9$. Because licensing the environmental technology does not improve the competitiveness of the local firm, the local firm has no incentive for technological transfer via licensing. As a result, there is no licensing agreement under the free trade regime.

3.2 No commitment to the tariff rate

In this section, we investigate the case where the tariff rate is determined after the licensing agreement. The timing of the game is as follows. In the first stage, the foreign firm offers a licensing contract with royalty r to the local firm. In the second stage, the local firm decides whether to accept the offer. In the third stage, the local government determines the tariff rate t. In the final stage, the firms engage in quantity competition.

We obtain the third stage equilibrium quantity and the tariff rate under no license as $q_e^{T,N} = \alpha(1+2\beta^2)/(9+2\beta^2), q_i^{T,N} = 4\alpha/(9+2\beta^2), t^{T,N} = \alpha/3 - 8\alpha\beta^2/3(9+2\beta^2)$. The first term of equation of $t^{T,N}$ is the tariff rate when there is no environmental damage. The second term is the marginal environmental damage generated by increasing the tariff by one unit. Therefore, $\partial[ED_i]/\partial q_i \cdot \partial q_i/\partial t = 8\alpha\beta^2/3(9+2\beta^2)$. In the absence of environmental policy, the local government considers the environmental impact in determining the tariff. Since the product of the local firm is associated with pollution and is not exposed to the tariff, the local government sets a lower tariff level to diffuse the green product of the foreign firm.

On the other hand, the third stage equilibrium quantity and tariff rate under a licensing contract become $q_e^{T,L} = (\alpha + 3r)/9, q_i^{T,L} = 2(2\alpha - 3r)/9, t^{T,L} = \alpha/3$. In summary, we obtain the following proposition.

Proposition 1. The optimal tariff is higher with licensing than without licensing: $t^{T,L} \geq t^{T,N}$.

Since there is no environmental damage under the licensing agreement, the local country can raise the tariff rate to protect its firm. We can derive the license fee satisfying $q_i^{T,N} = q_i^{T,L}$ as

$$r^* = \frac{4\alpha\beta^2}{27 + 6\beta^2}. \tag{3}$$

Profit increases when the local firm adopts the pollution-free technology; therefore, the license fee becomes positive.

When it licenses the technology, the profit of the foreign firm is

$$\pi_e^{T,L} = \frac{\alpha^2(9 + 60\beta^2 + 4\beta^4)}{9(9 + 2\beta^2)^2}. \tag{4}$$

$$\pi_e^{T,N} = \frac{\alpha^2(1 + 2\beta^2)^2)}{(9 + 2\beta^2)^2}. \tag{5}$$

Licensing occurs when $\pi_e^{T,L} \geq \pi_e^{T,N}$. Rearranging this condition and solving for β leads to the next proposition (see Appendices for proofs of propositions).

Proposition 2. Licensing occurs if and only if $\beta \leq 0.866$ when the foreign firm offers r^*.

Since $t^{T,L} \geq t^{T,N}$, the foreign firm faces a higher tariff by licensing its technology. As pointed out by Mukherjee and Pennings (2006), the foreign firm can offset the negative effect of higher tariff by the revenue from the license fee. When there is perfect IPR protection ($\beta = 1$), there is no licensing agreement. In this case, the local firm cannot imitate the technology, and consequently, the local government lowers the tariff rate to diffuse the product produced by the foreign firm. This, in turn, makes licensing unattractive for the foreign firm. On the other hand, when imitation is possible, the environmental damage is reduced through copying the technology. In this case, the local government does not have an incentive to lower the tariff rate. The difference between $t^{T,L}$ and $t^{T,N}$ becomes small and the licensing cost of the foreign firm is reduced. When one compares the social welfare of each country with and without the licensing agreement, one finds that $SW_e^{T,L} \geq SW_e^{T,N}$, $SW_i^{T,L} \geq SW_i^{T,N}$ and $SW_w^{T,L} \geq SW_w^{T,N}$ for $\beta \in (0, 0.866]$. Thus, in the case of no commitment and $\beta \in (0, 0.866]$, licensing activity enhances the welfare of all players.

3.3 Comparison

We compare the free trade equilibrium with no commitment under the licensing contract.

Proposition 3. World welfare is higher (resp. lower or even) under no commitment than under free trade, when $\beta \in (0.464, 0.866]$ (resp. otherwise).

The intuition of this proposition is as follows. When β is sufficiently small, environmental damage is avoided through imitation of the technology; thus, the benefit of licensing contract is very small. Consequently, it is beneficial to world welfare to adopt a free trade regime where there is no distortion of the tariff. In the case of $\beta > 0.866$, a licensing agreement does not take place under free trade or no commitment. Because a larger β and no licensing means greater environmental damage, it is beneficial for world welfare to remove the distortion of the tariff and diffuse the environmental friendly good. Therefore, free trade is desirable when $\beta > 0.866$.

A comparison of the social welfare of each country leads to the following proposition.

Proposition 4. When $\beta \in (0.754, 0.866]$ both countries prefer no commitment to free trade.

4 Commitment to the tariff rate

We consider the case where the local government can commit to a tariff rate. The timing of the game is as follows. In the first stage, the local government determines the tariff rate. In the second stage, the foreign firm offers royalty r to the local firm. In the third stage, the foreign firm decides whether to accept the offer. In the final stage, the firms engage in quantity competition.

The third stage equilibrium with and without the licensing contract can be characterized as $q_e^{C,L} = (\alpha - 2t + w)/3, q_i^{C,L} = (\alpha + t - 2w)/3, q_e^{C,N} = (\alpha - 2t)/3, q_i^{C,N} = (\alpha + t)/3$. Accordingly, we derive the license fee $r^C = 0$ such that $q_i^{C,L} = q_i^{C,N}$. This means that the local firm has no incentive to agree to the licensing offer. Moreover, under this licensing fee, licensing does not change the profit of the foreign firm; therefore, the foreign firm has no incentive to license its technology. Hence, there is no licensing agreement. In the first stage, the local government determines the tariff rate to maximize the social welfare of the local country. We obtain the optimal tariff rate as $t^C = \alpha/3 - 8\alpha\beta^2/3(9 + 2\beta^2)$. By calculating the equilibrium quantity, profit and social welfare for the case of commitment without a licensing agreement, we obtain the next proposition.

Proposition 5. The optimal tariff, domestic welfare, foreign welfare and world welfare are at least even or higher under no commitment than under prior commitment.

This result is the opposite of that of Kabiraj and Marjit (2003) and Mukherjee and Pennings (2006). This is because, in our analysis, licensing per se does not change the competitiveness of the local firm. In contrast to the case of no commitment, the tariff rate is fixed in the case of commitment; therefore, the local firm never has an incentive to pay for the technology.

5 Conclusion

This paper examined the welfare implications of the free trade regime and licensing agreement within a framework of international duopoly with global pollution. We have shown that free trade is not preferable if the protection of IPR is within a certain range. This implies that the protection of IPR beyond the range is a prerequisite for the justification of free trade. We have also revealed that the optimal tariff is higher with licensing than without it for no commitment to a tariff rate. Since there is no environmental damage under the licensing agreement, the local country can raise the tariff rate to protect its firm. In contrast, without licensing, the local government sets a lower tariff level and diffuse the product of the foreign firm. This is because the product of the local firm is associated with pollution when there is no licensing contract.

Appendix

The proof of Proposition 2

From (4) and (5), we obtain

$$\pi_e^{T,L} - \pi_e^{T,N} = \frac{8\alpha^2\beta^2(3-4\beta^2)}{9(9+2\beta^2)^2}. \tag{6}$$

Then, $\pi_e^{T,L} \geq \pi_e^{T,N}$ if $\beta \leq \sqrt{3}/2 \approx 0.866$.

Q.E.D.

The equilibrium value under the case of no-commitment

We obtain the result for the case of the no-commitment when $\beta \in (0, 0.866]$ as follows,

$$p^T = \frac{4\alpha(3+\beta^2)}{27+6\beta^2}, \quad q_e^T = \frac{\alpha(3+2\beta^2)}{27+6\beta^2}, \quad q_i^T = \frac{4\alpha}{9+2\beta^2}, \tag{7}$$

$$\pi_e^T = \frac{\alpha^2(9+60\beta^2+4\beta^4)}{9(9+2\beta^2)^2}, \quad \pi_i^T = \frac{16\alpha^2}{(9+2\beta^2)^2}, \tag{8}$$

$$SW_e^T = \frac{\alpha^2(9+60\beta^2+4\beta^4)}{9(9+2\beta^2)^2}, \quad SW_i^T = \frac{\alpha^2(189+36\beta^2+4\beta^4)}{6(9+2\beta^2)^2}, \tag{9}$$

$$SW_w^T = \frac{\alpha^2(585+228\beta^2+20\beta^4)}{18(9+2\beta^2)^2}. \tag{10}$$

When $\beta > 0.866$, licensing does not occur. In this case the result is denoted as follows,

$$p^T = \frac{4\alpha}{9+2\beta^2}, \quad q_e^T = \frac{\alpha(1+2\beta^2)}{9+2\beta^2}, \quad q_i^T = \frac{4\alpha}{9+2\beta^2}, \tag{11}$$

$$\pi_e^T = \frac{\alpha^2(1+2\beta^2)^2}{(9+2\beta^2)^2}, \quad \pi_i^T = \frac{16\alpha^2}{(9+2\beta^2)^2}, \tag{12}$$

$$SW_e^T = \frac{\alpha^2((1+2\beta^2)^2-16\beta^2)}{(9+2\beta^2)^2}, \quad SW_i^T = \frac{\alpha^2(7-2\beta^2)}{18+4\beta^2}, \tag{13}$$

$$SW_w^T = \frac{\alpha^2(65-28\beta^2+\beta^4)}{2(9+2\beta^2)^2}. \tag{14}$$

The proof of Proposition 3

We compare SW_w^F with SW_w^T when $\beta \in (0, 0.866]$ and have

$$SW_w^F - SW_w^T = \frac{\alpha^2(63-264\beta^2-132\beta^4-16\beta^6)}{18(9+2\beta^2)^2}. \tag{15}$$

Solving $(63-264\beta^2-132\beta^4-16\beta^6) = 0$ with respect to β we obtain $\beta \approx 0.464$. Therefore, $SW_w^F \geq SW_w^T$ if $\beta \in (0, 0.464]$ and $SW_w^F < SW_w^T$ if $\beta \in (0.464, 0.866]$. Comparing SW_w^F with SW_w^T when $\beta \in (0.866, 1)$, we have

$$SW_w^F - SW_w^T = \frac{\alpha^2(3-2\beta^2)(21+2\beta^2)(1+4\beta^2)}{18(9+2\beta^2)^2}. \tag{16}$$

Because we assume $\beta < 1$, $SW_w^F > SW_w^T$ when $\beta \in (0.866, 1)$.

Q.E.D.

The proof of Proposition 4

First, we compare the social welfare of the foreign country under the case of free trade with that of no-commitment. We compare SW_e^F with SW_e^T when $\beta \in (0, 0.866]$ and obtain

$$SW_e^F - SW_e^T = \frac{\alpha^2(72 - 105\beta^2 - 36\beta^4 - 4\beta^6)}{9(9 + 2\beta^2)^2}. \quad (17)$$

Solving $(72 - 105\beta^2 - 36\beta^4 - 4\beta^6) = 0$ with respect to β, we obtain $\beta \approx 0.754$. Threfore, $SW_e^F \geq SW_e^T$ if $\beta \in (0, 0.754]$ and $SW_e^F < SW_e^T$ if $\beta \in (0.754, 0.866]$. We compare SW_e^F with SW_e^T when $\beta \in (0.866, 1)$ and obtain

$$SW_e^F - SW_e^T = \frac{\alpha^2(3 - 2\beta^2)(24 + 37\beta^2 + 2\beta^4)}{9(9 + 2\beta^2)^2}. \quad (18)$$

Since we assume $\beta < 1$, $SW_e^F > SW_e^T$ when $\beta \in (0.866, 1)$.

Next, we compare the social welfare of the foreign country under the case of free trade with that of no-commitment. We compare SW_i^F with SW_i^T when $\beta \in (0, 0.866]$ and obtain the result,

$$SW_i^F - SW_i^T = -\frac{\alpha^2(81 + 54\beta^2 + 60\beta^4 + 8\beta^6)}{18(9 + 2\beta^2)^2} < 0. \quad (19)$$

We compare SW_i^F with SW_i^T when $\beta \in (0.866, 1)$ and obtain the result,

$$SW_i^F - SW_i^T = -\frac{\alpha^2(3 - 2\beta^2)^2}{18(9 + 2\beta^2)^2} < 0. \quad (20)$$

Q.E.D.

The proof of Proposition 5

We obtain the result for the case of the commitment as follows,

$$p^C = \frac{4\alpha}{9+2\beta^2}, \quad q_e^C = \frac{\alpha(1+2\beta^2)}{9+2\beta^2}, \quad q_i^C = \frac{4\alpha}{9+2\beta^2}, \tag{21}$$

$$\pi_e^C = \frac{\alpha^2(1+2\beta^2)^2}{(9+2\beta^2)^2}, \quad \pi_i^C = \frac{16\alpha^2}{(9+2\beta^2)^2}, \tag{22}$$

$$SW_e^C = \frac{\alpha^2((1+2\beta^2)^2-16\beta^2)}{(9+2\beta^2)^2}, \quad SW_i^C = \frac{\alpha^2(7-2\beta^2)}{18+4\beta^2}, \tag{23}$$

$$SW_w^C = \frac{\alpha^2(65-28\beta^2+\beta^4)}{2(9+2\beta^2)^2}. \tag{24}$$

From (11), (12), (13), (14), (**??**), (**??**), (**??**) and (**??**), we obtain the same results for the case of no-commitment and with-commitment when $\beta \in (0.866, 1)$. We compare t^N with t^C, SW_i^N with SW_i^C, SW_e^N with SW_e^C and SW_w^N with SW_w^C when $\beta \in (0, 0.866]$ and obtain the result, respectively,

$$t^N - t^C = \frac{8\alpha\beta^2}{3(9+2\beta^2)} > 0, \tag{25}$$

$$SW_i^N - SW_i^C = \frac{8\alpha^2\beta^2(3+\beta^2)}{3(9+2\beta^2)^2} > 0, \tag{26}$$

$$SW_e^N - SW_e^C = \frac{8\alpha^2\beta^2(21-4\beta^2)}{9(9+2\beta^2)^2} > 0, \tag{27}$$

$$SW_w^N - SW_w^C = \frac{8\alpha^2\beta^2(30-\beta^2)}{9(9+2\beta^2)^2} > 0. \tag{28}$$

Q.E.D.

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