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# “The Effects of Stronger Intellectual Property Rights on Technology Transfer : Evidence from Japanese Firm-level Data”


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**The Effects of Stronger Intellectual Property Rights on Technology Transfer : Evidence from Japanese Firm-level Data***

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***Abstract***

*It is noteworthy that intra-firm technology transfer has grown rapidly in recent years as a major part of international technology transfer. This paper presents empirical analysis of the effect of stronger Intellectual Property Rights (IPRs) on technology transfer from parent firm to its subsidiaries in foreign country. The results of empirical test, based on the firm-level panel data of Japanese MNCs' foreign subsidiaries, present that the stronger protection of IPRs has a positive effect on the promotion of intra-firm technology transfer after controlling market specific factors in the host countries as well as parent-subsidiary firm specific factors. They are consistent with our theoretical prediction and also the results of the previous studies based on US firm-level data.*

Keywords: Intellectual Property Rights, Technology Transfer, Multinational Firms, FDI

JEL Classification: C23, F20, F23, O30, O3

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## 1. Introduction

It is noteworthy that international technology transfer has grown rapidly in recent years. In addition to the increasing international trade of software and the brisk arm's length transaction of technology through international licensing contracts, intra-firm technology transfers, in particular, have become active due to the globalization of firms. Foreign direct investment (hereafter "FDI"), which has been increasing in recent years, transfers the technology for production with capital and management resources. FDI therefore is an important channel for current international technology transfer. As in the case of licensing contracts, technology transfer through FDI is envisaged to the delicate problem of technology spillover. As firms establish overseas production plants through FDI, they must embrace the problem that technology will spillover to local firms more easily as compared with the international trade of commodities. This will facilitate the local firms to catch up with the advanced technology of multinational firms. Since FDI involves the transfer of state-of-the-art technology from parent firms to their affiliates, the spillover of advanced technology through FDI becomes more serious than the technology outflow through licensing contracts. This is a major reason why the international rules in recent years have focused on agreements that prevent the free imitation of technology. A typical example is the conclusion of TRIPS agreement with GATT/WTO after which the WTO member countries have begun to strengthen the protection and enforcement of Intellectual Property Rights (hereafter "IPRs").

The issue regarding how largely the strengthening of IPRs affects technology transfers through licensing contracts and FDI is of great interest in international economics. Helpman (1993), Yang and Maskus (2001), and Glass and Saggi (2002) provided theoretical analyses of the effect of stronger IPRs on the innovation in the north and the economic welfare in the south. These studies present that how the strengthened IPRs affect the innovation and welfare depends on whether stronger IPRs promote the technology transfer. There are some empirical studies related to the effect of IPRs on the international transactions. Maskus and Penubarti (1995) showed that stronger IPRs encourage the imports using the industry-level data of manufacturing sectors in OECD and 25 developing countries. Lee and Mansfield (1996) presented that the weaker enforcement of IPRs in 14 developing countries reduces the FDI inflow from the United States and lowers the proportion of FDI in manufacturing and

R&D to total FDI by using firm-level data 14 U.S. chemical firms. Smith (1999, 2001) showed that stronger enforcement of IPRs in foreign countries increases the export from the United States and the sales of affiliate firms and the technology licensing of U.S. multinationals by using the data of the countries-pair transaction between the United States and foreign countries. Smith (2001) further showed that the enforcement of IPRs in foreign countries affect the sales of affiliate firms and the technology licensing more largely than the export to foreign countries.

It is essential to focus on the firm behavior because the technology transfer is closely related to corporate decision-making process. The previous studies, however, did not examine explicitly the effect of IPRS on the corporate decision. There are only a few empirical studies focusing on the effects of IPRs on the corporate decision of international transaction. Javorcik (2004) observed a positive correlation between the enforcement of IPRs and the decision on FDI by using the firm-level data of MNCs which invested in Eastern European countries and the former Soviet Union during 1989-1994. Branstetter *et al*. (2006) examined the effects of IPRs on technology transfer from U.S parent firms to their affiliate firms for the period 1982-1999 in 12 countries by using the panel data of U.S. firms and found a significant increase in the royalty fee when IPRs were strengthened in the host countries. There are no other empirical studies of technology transfers focusing on firm behavior as long as we know. The reason for such a limited number of empirical examinations at the firm level is due to the unavailability of data needed for empirical examinations. International technology transfers for country or industry are clarified to a certain extent as part of the balance of payments statistics. However, the availability of the firm-level data is extremely limited.

The purpose of this paper is to further examine the effect of stronger enforcement of IPRs on international technology transfer, along with the previous literatures. It, however, is different from previous studies in two points. First, it provides a theoretical framework based on the firm's decisions to examine whether the corporate decision of technology transfer is affected by stronger IPRs or not. It also presents how market-specific factors and firm-specific factors affect the firm-level decision of technology transfer. The idea of analytical framework is summarized as follows. A firm establishes its subsidiary which manufactures goods in the host country. The parent firm determines the level of manufacturing technology to be transferred to the subsidiary. In the host country, there exists a local firm that manufactures goods using imitated technologies. The foreign subsidiary and the local firm, which compete each other in the market of host country, decide the production volume in order to maximize their profits. As a result, a Cournot-Nash equilibrium is established in the market. The government of the host country is under the obligation to strengthen the IPRs in accordance with international agreements to limit the free imitation of technology. This increases the production cost for the local company. Since the stronger IPRs protection by the host country's government lowers the production activities of the local firm, this, in turn, will cause a rise in the production volume and profit of the foreign subsidiary, and also a positive effect on the optimal level of technology transfer determined by the parent firm which maximizes the profit for the group of parent and subsidiary firms. This theoretical framework predicts that the stronger protection of IPRs accelerates technology transfer.

The second contribution of this paper is the unique empirical test of the theoretical framework that stronger international IPRs accelerate technology transfers, based on the panel data of Japanese multinational firms. The use of firm-level data is indispensable for empirical analysis of corporate strategy such as technology transfer. Some studies used firm-level data of Europe and the United States; however, there is considerable scope for improvement since the coverage of data is insufficient. As mentioned before, technology transfers occur between a parent firm and its affiliate as well as in the form of arm's length licensing contracts. In this paper, we chose the former as an objective for analysis since it is difficult to obtain firm-level data for the latter. In this study, empirical analysis is carried out using the micro-level data of Japanese firms with a large sample size included in the *Basic Survey of Overseas Business Activities* and the *Basic Survey of Corporate Activities* conducted by the Ministry of Economy, Trade and Industry. The results of the empirical analysis have revealed that stronger IPRs have a positive effect on the promotion of intra-firm technology transfers.

The analyses of this paper will positively support the motivation of international efforts to the establishment and harmonization of appropriate enforcement of IPRs under the international framework including WIPO and WTO.

The remainder of this paper is structured as follows. In the following section, we present a theoretical framework to analyze the effect of IPRs protection on technology transfer. Section 3 presents the equation and methodology for the empirical estimation. Section 4 presents the data used for the empirical analysis and the estimated results. The final section comprises our conclusion and discusses remaining issues.

## 2. Theoretical Framework

### 2.1 Model Structure

The means of technology transfer are not simple. There are various channels of technology transfer including international trade of goods and services, licensing contracts, and international movements of engineers as well as the supply of technology from a parent to its subsidiary through FDI. As mentioned in the previous section, this section presents a framework for analyzing the effect of stronger IPRs on technology transfer from the parent firm to its subsidiary in the host country. Technology transfer through FDI can be divided into two stages: In the first stage, technology flows from the parent company to its subsidiary, and in the second stage, the technology held by the subsidiary is diffused to the local companies. In this paper, we focus on the first stage as a subject of analysis. When we consider technology transfer as a process that ultimately ends in the diffusion of technology to the local economy, the second stage is an indispensable process as the technology transfer. However, the second stage of technological diffusion occurs through various routes and is extremely difficult to be specified by statistical data. Therefore, this paper concentrates the analysis to the first stage.

The structure for the analysis is as follows. There are two firms in host country H, firm H and firm F: firm H is the local firm whose manufacturing technology is obtained through imitation, firm F is the subsidiary of a parent firm located in country F. The manufacturing technology used by the subsidiary firm is transferred from the parent firm. We assume that the two firms form a duopoly of the Cournot-Nash type in the host country's market. In other words, both firms manufacture the same goods which are sold only in the host country's market.

For simplification, we define the demand for the goods as follows:

$$p(x + x^*) = a - (x + x^*) \qquad (1)$$

where $x$ and $x^*$ indicate the production volume of firm H and firm F, respectively, $a$ is the market size, and $p$ is the price. The profit of the local firm H, $\pi$, is defined as follows:

$$\pi(x, x^*, c, \tau) = xp(x + x^*) - c\tau x \qquad (2)$$

where $c$ denotes the given marginal cost of production, and $\tau$ indicates the imitation cost of production technology. An increase in $\tau$ implies an increase in the imitation cost, thereby increasing the marginal cost. Hence, strengthening the IPRs in the host country causes an increase in $\tau$.

The profit of the firm F, $\pi^*$, is defined as follows:

$$\pi^*(x, x^*, c^*, T) = x^* p(x + x^*) - \frac{c^*}{T} x^* - mT \qquad (2^*)$$

where $c^*$ denotes the given marginal cost of production, and $T$ denotes the level of the technology transferred from the parent firm to firm F. The second term in the right-hand side of equation (2*) implies that an increase in the amount of technology $T$ transferred from the parent firm raises the productivity of the subsidiary firm, and hence, lowers the marginal cost of production. We assume that the firm F must pay an additional cost $m$ to absorb a unit of technology transferred from the parent firm. The firm F also must pay an amount of the royalty fee to the parent firm for a compensation of technology transferred. The royalty fee, on the other hand, is the revenue of parent firm. The royalty payment of the subsidiary to the parent firm is cancelled out by the receipt of the parent firm as we assume that the strategy of parent firm is to maximize the total profit of parent and affiliate firms. Therefore we omit the royalty payment of the subsidiary to the parent firm in equation (2*).

### 2.2 Optimal Level of Transferred Technology

The variables to determine the market equilibrium are (i) the production volumes of the two firms, (ii) the IPRs policy determined by the government of host country H, and (iii) the amount of technology transferred from the parent firm. Let us assume a multi-stage one shot game in the decision of the optimal level of transferred technology as follows:

(1) The government of country H determines the level of IPRs protection $\tau$ under the

international obligation. One example is the strengthening of the protection of Patent Right based on the WTO/TRIPS agreement.

(2) In response to the stronger IPRs protection, the parent firm of firm F determines the level of technology $T$ to be transferred to firm F so as to maximize the profit of firm F.

(3) Both firm H and firm F simultaneously determine their production volumes, $x$ and $x^*$, respectively, in order to maximize their profits under the given IPRs protection level and the given level of technology transferred. We assume that the firm F follows the decision of the parent firm.

The backward induction of this multi-stage one shot game leads to the following equilibrium. First, equations (3) and (3*) are obtained from the first-order conditions to maximize the profits, $\pi$ and $\pi^*$, respectively:

$$\pi_x = a - 2x - x^* - c\tau = 0 \tag{3}$$

$$\pi^*_{x^*} = a - 2x^* - x - \frac{c^*}{T} = 0 \tag{3*}$$

The optimal production volumes of the two firms are shown below:

$$x = \frac{1}{3}\left\{a - 2c\tau + \frac{c^*}{T}\right\} \tag{4}$$

$$x^* = \frac{1}{3}\left\{a + c\tau - 2\frac{c^*}{T}\right\} \tag{4*}$$

Further, the total supply of goods and their market price are given as follows:

$$x + x^* = \frac{1}{3}\left\{2a - c\tau - \frac{c^*}{T}\right\} \tag{5}$$

$$p = \frac{1}{3}\left\{a + c\tau + \frac{c^*}{T}\right\} \tag{6}$$

From equations (2*), (4*), (5) and (6), the profit of firm F is expressed as follows:

$$\pi^*(c, c^*, \tau, T) = \left\{\frac{1}{3}\left[(a + c\tau - 2\frac{c^*}{T}\right]\right\}^2 - mT \tag{7}$$

As we assume that the parent firm of firm F determines technology level $T$ so as to maximize $\pi^*$, the first-order condition of equation (7) with respect to $T$ leads to the following equation:

$$\frac{\partial \pi^*}{\partial T} = \frac{4c^*}{9}\left\{a + c\tau - 2\frac{c^*}{T}\right\}\left[\frac{1}{T}\right]^2 - m = 0 \,. \tag{8}$$

From the equation (8), the optimal level of transferred technology, denoted by $T^*$, is determined by the IPRs protection level $\tau$, the absorption cost $m$ and marginal costs $c$ and $c^*$, under a given market size $a$ :

$$\frac{9}{4c^*} mT^{*3} - (a + c\tau)T^* + 2c^* = 0 \tag{9}$$

### 2.3 Effect of Changes in IPRs on Technology Transfer

By taking a total differentiation of equation (9) with respect to the optimal technology level $T^*$ and the IPRs protection level $\tau$, the effect of change in the IPRs protection $\tau$ on the optimal technology level $T^*$ is expressed as follows:

$$\frac{dT^*}{d\tau} = \frac{cT^*}{\frac{27}{4c^*} mT^{*2} - (a + c\tau)} \tag{10}$$

Equation (10) implies that $\frac{dT^*}{d\tau} > 0$ if $T^* > \left[\frac{4c^*}{27m}(a + c\tau)\right]^{\frac{1}{2}}$. In other words, the stronger protection of IPRs, that is a rise of $\tau$, results in the increase of technology transfer under the condition that the optimal technology level $T^*$ is beyond a certain level.

The marginal effect of absorption cost of transferred technology on its level is expressed as follows:

$$\frac{dT^*}{dm} = -\frac{9T^{*3}}{4c\left[\frac{27}{4c^*} mT^{*2} - (a + c\tau)\right]} \tag{11}$$

We obtain that $\dfrac{dT^*}{dm} < 0$ if $T^* > \left[\dfrac{4c^*}{27m}(a + c\tau)\right]^{\frac{1}{2}}$.

The theory of "learning by doing" leads to that the larger the R&D expenditure of the firm, the higher the capability to absorb new technology. We also assume that the subsidiary's capability to absorb new technology reflects the absorption capability of the parent firm. Then, we assume that the larger R&D expenditure of the parent firm induces the lower cost of the subsidiary firm to absorb the transferred technology. Under this assumption, we predict that the absorption cost of the subsidiary is lower if R&D expenditure of parent firm is larger. This is thought as a parent-subsidiary pair effect. From the above, we can derive the following proposition:

**Proposition**: In the region where transferred technology exceeds a certain level, the stronger IPRs protection in host country and the larger R&D expenditure of the parent firm in home country will lead to an increase in the optimal level of technology transfer.

**3. Model Specification for Empirical Test**

The purpose of this section is to empirically test whether the result of the theoretical analysis mentioned in the previous section can be applicable to the explanation of the real transaction, by using firm-level data of technology transfers between parent and its subsidiaries of Japanese multinational firms. Under the theoretical model the empirical analysis is performed to test whether the stronger IPRs protection in the host country and the larger R&D expenditure of parent raise the level of technology transfer.

The following form is used for estimation to empirically test the effects of the factors in equations (10) and (11).

$$\begin{aligned} ln\,TF_{ilt} = \alpha + \beta_1 \, ln\, IPR_{jt} + \beta_2 \, ln\, P\_R\&D_{it} + \gamma_1 \, ln\, EMP_{ilt} + \gamma_2 \, ln\, MSIZE_{jt} \\ + \gamma_3 TAX_{jt} + u_{il} + \varepsilon_{ilt} \end{aligned} \tag{12}$$

where $TF_{ilt}$ denotes the optimal level of technology transfer by the parent firm *i* to the subsidiary firm $l$ in the period *t*, $IPR_{jt}$ denotes the level of IPRs protection in country *j*, $P\_R\&D_{it}$ denotes the R&D expenditure of the parent firm *i* in the period *t*. $EMP_{ilt}$, $MSIZE_{jt}$ and $TAX_{jt}$ are included in equation (12) for controlling market and firm specific factors.

$TAX_{jt}$, defined by the difference in corporate tax rate between the host country and Japan, represents the effect of transfer pricing on technology transfer caused by the difference in corporate tax rate between Japan and the host country. If the corporate tax rate in the host country rises, affiliate firms tend to remit their profits as a pose of royalty payments in order to save the tax payment. Therefore, the royalty payments for technology transfer may be distorted by the difference in tax rate between two countries if the affiliate firms execute the royalty payment as a toll of transfer pricing. Hines (1995) and Grubert (1998) showed that the distortion of intra-firm royalty payment caused by the difference in tax rates among countries should be controlled by the tax rate in host country. Along with the previous studies, we control the effect of transfer pricing by including the difference in corporate tax rate between the host country and Japan in the equation. It is expected that the increase of corporate tax rate in the host country causes the transfer pricing of the affiliates to reduce their tax payment. We predict the coefficient of $TAX_{jt}$, which is defined by the corporate tax rate in the host country minus the one in Japan, to be positive.

$EMP_{ilt}$, which denotes the size of subsidiary firm $l$ measured by the number of employees in the period *t*, is used for controlling the effect of affiliate's size. $MSIZE_{jt}$ is used to control the effect of market size of the host country. α is the constant, $u_{il}$ represents the individual effect of the subsidiary *i*, *l*, and $\varepsilon_{ilt}$ is the idiosyncratic error term distributed as iid.

The results of theoretical analysis in the previous section predict the signs of coefficients as follows:

$\beta_1 > 0$ from equation (10) and $\beta_2 > 0$ from equation (11)

We also statistically investigate whether the changes in the level of IPRs protection affect the optimal level of technology transfer. The following equation (13) which is constructed by taking the rate of changes and the difference between two periods for the variables in equation (12) is used for estimation.[1]

$$\ln\left[\frac{TF_{ilt}}{TF_{ilt-1}}\right] = \beta_1 \ln\left[\frac{IPR_{jt}}{IPR_{jt-i}}\right] + \beta_1 \ln\left[\frac{P\_R\&D_{it}}{P\_R\&D_{it-1}}\right] + \gamma_1 \ln\left[\frac{EMP_{ilt}}{EMP_{ilt-1}}\right]$$
$$+ \gamma_2 \ln\left[\frac{MSIZE_{jt}}{MSIZE_{jt-1}}\right] + \gamma_3\left[TAX_{jt} - TAX_{jt-1}\right] + \varepsilon_{ijl} \qquad (13)$$

The constant term α and the term $u_{il}$ presenting the individual effect of the subsidiary *i* are no longer included in this model.

## 4. Data and Results of Estimation

### 4.1 Data and Variables

The empirical examination of this paper is characterized by the use of rich Japanese firm-level panel data. We use the firm-level data of the *Basic Survey of Overseas Business Activities* as the source for Japanese subsidiaries located in foreign countries and those of the *Basic Survey of Corporate Activities* as the source for parent firms. Both statistics are supplied by the Ministry of Economy, Trade and Industry. Due to the limited availability of the index of IPRs, the data for estimation cover two years: 1995 and 2001. The affiliates whose payment for technology transfer is missing are excluded from the sample, but the affiliates whose payment record zero are included in the sample. For the use of maximum sample size of the data, we construct an unbalanced panel data by matching the data of host countries with the firm-level data. In fact, the unbalanced panel data include 2,269 observations of Japanese MNC's affiliates in 33 countries. The data for estimating the effect of changes in explanatory variables on the change in technology transfer between two years covers, 680 affiliates in 28 countries.

[1] Although the coefficients of equation (13) are predicted to be same as the estimated results of equation (12), they are not exactly same due to the difference in the sample size.

As a dependent variable $TF_{ilt}$ , we use the "affiliate's royalty payment to its shareholders in Japan" of the *Basic Survey of Overseas Business Activities* defined by the payment of foreign subsidiaries to their parent firm in manufacturing sector. We computed the real value of payments denoted in Japanese yen in 2001 by using the GDP deflator in *World Development Indicators* and the exchange rate changes between yen and local currency.[2]

We use the "Index of Patent Right" (hereafter "*IPR*") by Park and Wagh (2002) as a proxy of the level of IPRs protection in each country. This index investigates the degree of patent right protection in the following 5 categories: (1) the coverage of patentability for major industries including pharmaceuticals, chemicals, and food, (2) the duration of patent rights, (3) the strictness of legal enforcement, (4) the ratification of international agreements related to the patent protection, and (5) the existence of policies that undermine the implementation of patent rights. A score between 0 and 5 is allotted to each item according to the fulfillment. The index is constructed by the summation of the score of each item. Higher score of the index represents a country with a higher level of patent protection. Since the *IPR* is updated every 5 years, we have chosen two years, 1995 and 2000 for the estimation. The estimation in this paper covers the establishments of Japanese subsidiaries in 35 countries which are matched to the coverage of the *IPR* index by Park and Wagh (2002).

Table 1 presents the number of affiliates, total royalty payments and the IPR index by countries. The distribution of royalty payments is heavily skewed among countries.[3] The payment of Japanese affiliates in the United States accounts for half of the royalty payments of all Japanese affiliates in 1995, and about a third of them in 2001. On the other hand, we find a remarkable increase in the royalty payments of Japanese affiliates in Asian countries, especially for Indonesia and China. The changes in the IPR index between 1995 and 2000 present that most of countries have experienced the reform of IPRs.

Table 2 shows the number of affiliates and the royalty payments by industries. The technology transfer is concentrated to chemicals and pharmaceuticals, general machinery, electrical machinery and transport machinery. We include 3-digit industry dummy variables in the estimation

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[2] In case of zero value for royalty payments, we add unit value for taking natural logarithm.
[3] The similar observation is mentioned in Belderbos (2003) and Iwasa and Odagiri(2004).

equation for controlling the industry specific factors.

Table 1 and Table 2

The R&D expenditure of each parent firm (*P_R&D*) is calculated by the firm-level data of the *Basic Survey of Overseas Business Activities*. The number of employees (*EMP*) is collected from the firm-level data of the *Basic Survey of Overseas Business Activities*. The difference in corporate tax between the host countries and Japan (*TAX*) is calculated from the *Corporate Tax Rate Survey* published by KPMG. The total industrial value added of each country *(MSIZE)* is collected from *World Development Indicators*. The statistical description of each data is shown in Tables 3 and 4.[4]

Table 3 and Table 4

### 4.2 Methods and Results of Estimation

We conduct the estimation by applying random effects model to equation (12) based on the unbalanced panel of 1995 and 2001[5] as well as carrying out the panel Tobit with random effects model to solve the problem that a large number of affiliates record zero value for the amount of royalty payment. 3-digit industry dummy variables are included in estimation equation to control industry specific factors. Table 5 presents the summary of the estimated results of equation (12). The results of Breusch-Pagan test demonstrate that the random effects model is favorable in comparison with the OLS estimation based on pooling data.

Table 5

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[4] The royalty payment, the R&D expenditure and the total industrial value added are deflated by the GDP deflator and expressed in the price of 1995.

[5] Since the data we use is unbalanced panel of two years, the fixed effects model can not be applied. The result of our estimation based on the balanced data does not show a different result from the estimation based on the unbalanced data. Baltagi and Chang (1994) show that estimating only balanced data extracted from unbalanced data fully loses validity. Therefore, we present only the results of estimation based on the unbalanced data.

**a. IPRs Protection**

It is notable that the coefficient of *IPR* is positive with a statistical significance for both the case [1] and [2]. In the case of the random effects model ([1] Random), the elasticity is 0.536. In the case of panel Tobit estimation ([2] Tobit), *IPR* coefficient is also positive at 0.727 with a statistical significance.[6] These results clearly indicate that the intra-firm technology transfer is accelerated in the host countries in which the protection of IPRs is strong.

**b. R&D Expenditure of Parent Firm**

As a proxy of absorption cost, we used the R&D expenditure carried out by the parent firm. The coefficient for R&D expenditure of the parent firm is positive with a statistical significance of 1% in both the estimation of the random effects model and the panel Tobit estimation. The elasticity is between 0.08 for [1] Random and 0.12 for [2] Tobit. The estimation results, presenting that the larger R&D expenditure of parent firm raises the optimal level of technology transfer, are consistent with our theoretical prediction that the abundance of technological knowledge of the parent firm accelerates the technology transfer of affiliates by lowering their absorption cost.

**c. Size of Affiliates**

The coefficients of the number of employees indicating the size of the subsidiary are significantly positive in both cases, while their values vary. The elasticity in the case of the panel Tobit estimation is greater than 1. It is natural that the larger size of affiliates increases the volume of technology transferred from the parent firm.

**d. Market Specific Factors**

It is noted that the coefficient of *TAX* is positive and significant at 1% level in the both cases. This result means that Japanese affiliates in the countries with a higher tax rate tend to pay more money for a compensation of technology transfer. This suggests that Japanese affiliates might have used the royalty payment as a toll of transfer pricing when the tax rates differ between Japan and the host countries.

The market size of host country is found a negative effect on technology transfer. This is

[6] While we have omitted from the table, we found the result that the Tobit estimation using panel data is more appropriate than the Tobit estimation using pooling data, according to the log likelihood.

contradictory to the theoretical prediction that the larger size of the market will accelerate the technology transfer. However, looking at the distribution of countries by market size, we confirmed that there exist two different groups of countries: one is the group of countries for large market size and another is for small market size. If the propensity of market size to the increase in technology transfer is completely different between two groups, the estimation using the pooled data of different groups, for the purpose of remaining the sufficient sample size, may be inadequate.

e**. Changes in IPRs Protection**

Table 6 shows the results of estimation for equation (13). The coefficients of the changes for the IPRs Index, the size of affiliates and the corporate tax rate are positive with a high statistical significance, while those for the R&D expenditure of the parent firm and the market size of host country are not. It is notable that the stronger enforcement of IPRs and the increase in the size of affiliates raise the volume of technology transfer after controlling the effect of changes in the corporate tax difference between the host country and Japan.

Insert Table 6

The above statistical evidences suggest that stronger IPRs accelerate intra-firm technology transfer with a high statistical significance even after controlling the market and firm-specific factors. As predicted in our theoretical discussion, we can conclude that the strengthening of the IPRs between 1995 and 2001 has positively contributed to an increasing volume of international technology transfer during this period.

## 5. Conclusion

The issue with respect to whether the stronger enforcement of IPRs under the agreement of WTO/TRIPS has accelerated the international transfer of technology attracts an enormous interest. As long as the authors know, a survey of the previous literatures reveal that very few studies have been attempted at the firm level although the effect of changes in IPRs on technology transfer is an aspect of firm-level decision. This paper presents a theoretical framework, based on the firm-level decision, with regard to how stronger IPRs affect the intra-firm technology transfer, after controlling the market-specific factors in the host country and the firm-specific factors. Based on the theoretical framework, we carried out empirical tests to examine whether stronger IPRs promote intra-firm technology transfer across borders. Our statistical examination is the first attempt to use Japanese firm-level panel data which is constructed by matching the data of Japanese parent firms and their foreign subsidiaries to the data in the host country including the index of IPRs protection. The results of the empirical analysis clearly show that IPRs protection has a positive effect on intra-firm technology transfer after controlling the market- and firm-specific factors including the R&D expenditure of parent firm, the size of subsidiary, the difference in corporate tax rate between host country and Japan, and the market size in the host country. They reveal that technology transfers between parents and their subsidiaries is accelerated in countries with a high level of IPRs protection. We also carry out the empirical examination by using the data for the rate of change between two periods, the years 1995 and 2001. The estimation results confirmed that the strengthened protection of IPRs during the period increased the volume of technology transferred.

The results in this paper, which are also consistent with Javorcik (2004) and Branstetter *et al.* (2006) that attempted empirical tests by using the data of Europe and the US firms, lead to a policy implication that the international agreement to enforce the IPRs protection should be encouraged for promoting the international technology transfer by MNCs.

Lastly, we conclude by describing the remaining issues for further examination. In addition to intra-firm technology transfer between the parent firm and its subsidiary, we observe many licensing contracts for technology transfer under arm's length transaction. This paper does not cover this issue because of the limitation in the availability of sufficient firm-level data. Although this paper has employed the index proposed by Park and Wagh (2002) as a proxy of IPRs protection of the host country, this index does not necessarily clearly indicate the timing in which the changes in IPRs protection actually occurred. These are the subjects to be further examined. In order to resolve them, we need the development of theoretical framework to incorporate the arm's length transaction of technology in the model and the availability of the data for arm's length transaction of technology as well as the information that indicates the content and timing of changes in the IPRs protection policy.

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Table 1: Distribution of subsidiaries, royalty payments and *IPR* over countries

| Country | the number of obs. | Total royalty payments (million Yen) | | Index of Patent Right by Park and Wagh (0~5) | |
|---|---|---|---|---|---|
| | | 1995 | 2001 | 1995 | 2000 |
| Argentina | 4 | 71 | 0 | 3.19 | 3.33 |
| Australia | 42 | 3,447 | 4,817 | 3.86 | 4.19 |
| Belgium | 28 | 1,518 | 555 | 3.90 | 4.05 |
| Brazil | 50 | 1,056 | 169 | 3.05 | 3.05 |
| Canada | 28 | 7,666 | 3,505 | 3.57 | 3.90 |
| Chili | 1 | 0 | - | 3.07 | 3.41 |
| China | 357 | 3,353 | 12,199 | 1.55 | 2.48 |
| Colombia | 4 | 360 | 150 | 2.57 | 3.24 |
| Czech Republic | 2 | 0 | 0 | 3.19 | 3.52 |
| Denmark | 4 | 20 | 0 | 4.05 | 4.19 |
| France | 47 | 3,281 | 4,695 | 4.05 | 4.05 |
| Germany | 105 | 4,219 | 5,667 | 3.86 | 4.52 |
| Greece | 2 | 72 | 178 | 2.65 | 3.19 |
| Guatemala | 1 | 6 | - | 1.08 | 1.70 |
| Hong Kong | 87 | 4,587 | 1,417 | 2.57 | 2.90 |
| Hungary | 3 | 369 | 563 | 3.37 | 3.71 |
| India | 30 | 1,181 | 3,891 | 1.51 | 2.18 |
| Indonesia | 156 | 5,236 | 35,552 | 1.24 | 2.27 |
| Ireland | 2 | 147 | 2,368 | 3.32 | 4.00 |
| Italy | 10 | 61 | 663 | 4.19 | 4.33 |
| Korea | 127 | 4,695 | 3,637 | 4.20 | 4.20 |
| Mexico | 36 | 310 | 3,107 | 2.86 | 2.86 |
| Netherlands | 44 | 904 | 2,562 | 4.38 | 4.38 |
| New Zealand | 14 | 55 | 11 | 3.86 | 4.00 |
| Poland | 2 | 0 | 197 | 2.90 | 3.24 |
| Singapore | 156 | 14,945 | 9,897 | 3.90 | 4.05 |
| Spain | 29 | 482 | 1,101 | 4.05 | 4.05 |
| Sweden | 5 | 0 | 0 | 4.24 | 4.38 |
| Thailand | 237 | 19,651 | 23,326 | 2.24 | 2.24 |
| Turkey | 3 | 562 | 2,100 | 1.80 | 2.86 |
| United Kingdom | 112 | 3,679 | 4,490 | 3.57 | 4.19 |
| United States | 540 | 71,398 | 58,880 | 4.86 | 5.00 |
| Venezuela | 1 | - | 0 | 2.90 | 2.90 |
| *Total or Mean* | *2,269* | *153,331* | *185,695* | *3.20* | *3.53* |

Note: This table is based on the unbalanced panel data. “-” indicates no observations in the sample of the year. Royalty payments in 2001 are expressed in the yen value of the 1995 price by applying the GDP deflator from WDI and the yen-local currency exchange rate as reported in the METI survey.

Table 2: Distribution of royalty payments over industries

| Industry | number of observations | Total of royalty payments 1995 | 2001 |
|---|---|---|---|
| Food and drinks | 127 | 1,583 | 3,806 |
| Textiles | 116 | 407 | 242 |
| Wood and pulp | 33 | 364 | 997 |
| Chemicals and pharmaceuticals | 283 | 11,916 | 33,204 |
| Oil | 20 | 53 | 259 |
| Building materials | 58 | 321 | 895 |
| Steel | 57 | 198 | 232 |
| Nonferrous metals | 45 | 693 | 951 |
| Metal | 46 | 214 | 803 |
| General machinery | 188 | 11,336 | 9,541 |
| Electrical machinery | 619 | 40,183 | 69,140 |
| Transport machinery | 408 | 76,967 | 62,683 |
| Precision machinery | 99 | 3,703 | 932 |
| Other manufacturing | 170 | 5,393 | 2,011 |
| *Total* | *2,269* | *153,331* | *185,695* |

Table 3: Descriptive statistics (1)

| | 1995 | | | 2001 | | |
|---|---|---|---|---|---|---|
| Variable | obs. | Mean | Std. Dev | obs. | Mean | Std. Dev |
| *TF* : royalty payments from affiliates to parent(million Yen) | 1147 | 133.7 | 1217.8 | 1122 | 165.7 | 804.4 |
| *IPR* : Index of Patent Rights (0~5) | 1147 | 3.34 | 1.28 | 1122 | 3.60 | 1.08 |
| *P_R&D* : parent R&D expenditures (million Yen) | 1147 | 28094.4 | 55680.0 | 1122 | 41290.8 | 74563.6 |
| *EMP* : the number of affiliate's employee | 1147 | 455.5 | 1523.8 | 1122 | 564.4 | 1749.8 |
| *MSIZE* : total industrial value added (million $) | 1147 | 528,000 | 666,000 | 1122 | 609,000 | 732,000 |
| *TAX* : the difference in corporate tax rate (%) | 1147 | -17.6 | 6.5 | 1122 | -8.5 | 5.7 |

Table 4: Descriptive statistics (2)

| Variable | obs. | Mean | Std. Dev |
|---|---|---|---|
| $\ln(TF_t/TF_{t-1})$ | 680 | 0.549 | 2.026 |
| $\ln(IPR_t/IPR_{t-1})$ | 680 | 0.145 | 0.200 |
| $\ln(P\_R\&D_t/P\_R\&D_{t-1})$ | 680 | 0.400 | 1.452 |
| $\ln(EMP_t/EMP_{t-1})$ | 680 | 0.200 | 1.039 |
| $\ln(MSIZE_t/MSIZE_{t-1})$ | 680 | 0.195 | 0.166 |
| $TAX_t-TAX_{t-1}$ | 680 | 9.018 | 2.202 |

Table 5: Estimated Results (1)

Dependent Variable: ln *TF* (Royalty Payments from Subsidiaries to Their Parent Firm)

| | [1]Random | [2]Tobit |
|---|---|---|
| ln(*IPR*): "Index of Patent Rights" in the host country | 0.536 | 0.727 |
| | [0.135]** | [0.231]** |
| ln(*P_R&D*): R&D expenditures of Japanese parent firms | 0.084 | 0.120 |
| | [0.016]** | [0.028]** |
| ln(*EMP*): the number of affiliate's employee | 0.633 | 1.157 |
| | [0.028]** | [0.053]** |
| ln(*MSIZE*): total industrial value added in the host country | -0.163 | -0.282 |
| | [0.036]** | [0.062]** |
| *TAX*: the corporate tax rate in host country minus the one in Japan | 0.025 | 0.047 |
| | [0.007]** | [0.012]** |
| Industry dummy variables | Yes | Yes |
| Constant | 2.255 | 1.278 |
| | [0.986]* | [1.681] |
| the number of observations | 2,269 | 2,269 |
| the number of groups | 1,588 | 1,588 |
| R-sq: within | 0.121 | |
| between | 0.328 | |
| overall | 0.320 | |
| Breusch-Pagan Lagrangian multiplier test (pooling vs random effects) | chi-sq = 178.7 Pr>chi-sq = 0.000 | |

Note: The numbers of parentheses present standard errors.
* and ** indicate the statistical significance with 5 percent and 1 percent, respectively.
As for panel-Tobit with random effects estimation, there were 1,167 left-censored observations, namely zero values in the sample. Tobit estimation using panel data is more appropriate than the Tobit estimation using pooling data, according to the log likelihood.

Table 6: Estimated Results (2)

Dependent Variable: $\ln\left[\frac{TF_{ilt}}{TF_{ilt-1}}\right]$

| | OLS |
|---|---|
| $\ln(IPR_t/IPR_{t-1})$ | 0.880 |
| | [0.369]* |
| $\ln(P\_R\&D_t/P\_R\&D_{t-1})$ | 0.002 |
| | [0.045] |
| $\ln(EMP_t/EMP_{t-1})$ | 0.509 |
| | [0.115]** |
| $\ln(MSIZE_t/MSIZE_{t-1})$ | -0.361 |
| | [0.504] |
| $TAX_t-TAX_{t-1}$ | 0.040 |
| | [0.013]** |
| The number of observations | 680 |
| R-sq | 0.14 |

Note: The numbers of parentheses present robust standard errors.
* and ** indicate the statistical significance with 5 percent and 1 percent, respectively.