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Does the Structure of Multinational Enterprises' Activity Affect Technology Spillovers?*

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Abstract

We examine how the structure of multinational enterprises' (MNEs') activity affects technology spillovers between MNEs and their host economies by using firm-level data of Japanese MNEs and patent citations data. We construct new measures of foreign direct investment (FDI) by exploiting information on sales and purchases of foreign affiliates of MNEs. Pure horizontal (vertical) FDI is defined as FDI with a high share of transactions (i.e., both purchases of inputs and sales of outputs) in the local market (with the home country). Partially horizontal and vertical FDI are also defined. We then estimate the effects of these types of FDI on technology spillovers captured by patent citations. Our findings reveal that when developed economies host Japanese MNEs, pure vertical FDI has significantly positive effects on technology spillovers in both directions. When developing economies host Japanese MNEs, by contrast, no form of FDI significantly facilitates technology spillovers in either direction.

Keywords: technology spillovers, patent citations, FDI, and multinationals.
JEL classification: F10; F23; O3; L2

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1 Introduction

Foreign direct investment (FDI) and international trade are two major channels of international technology spillovers (Keller, 2004, 2009). While a number of empirical studies confirm significant technology spillover effects through imports, empirical findings on technology spillover effects through FDI are mixed. In particular, there is relatively little evidence of technological spillovers from inward FDI to the host country's firms in the same industry. For example, Haskel, Pereira, and Slaughter (2007) examine the situation in the United Kingdom and find significantly positive technology spillovers from FDI. Keller and Yeaple (2009) also provide similar results for the United States. By contrast, Aitken and Harrison (1999) and Haddad and Harrison (1993) find no significant or only weak technology spillovers from FDI for developing countries hosting FDI (the former analyzes the case of Venezuela and the latter the case of Morocco).[1] Todo (2006) and Todo and Miyamoto (2006) find that research and development (R&D) activities play an important role in technological spillovers from FDI to local firms in the same industry. That is, a positive, statistically significant spillover effect is observed only for R&D-performing foreign firms (in Indonesia) or foreign firms' R&D stock (in Japan). In contrast, a number of studies find significant technological spillovers from inward FDI to the host country's upstream firms through backward linkages. These studies include Javorcik (2004) for the case of Lithuania, Javorcik and Spatareanu (2008) for the case of Romania, and Blalock and Gertler (2008) for the case of Indonesia.[2] Moreover, Branstetter (2006) and Singh (2007) find evidence of technology spillovers from outward FDI. That is, firms investing in foreign countries acquire technological knowledge from other firms in the host countries.

When a firm establishes business enterprises in two or more countries through FDI, it becomes a multinational enterprise (MNE). Although actual patterns of FDI are very complex, the types of FDI and MNE's activities have been usually categorized into horizontal and vertical.[3] Horizontal FDI replicates a subset of the production process in foreign countries to serve local markets (Markusen, 1984, 1995; Markusen and Venables, 1998, 2000; Brainard, 1993, 1997; Helpman, Melitz, and Yeaple, 2004). It is often motivated by a desire to reduce transportation costs. In contrast, vertical FDI involves geographical fragmentation of the production process and is often motivated by a desire to take advantage of factor cost differentials (Helpman, 1984, 1985; Helpman and Krugman, 1985; Venables, 1999). Recently, Yeaple (2003a) proposed a model in which horizontal, vertical, and complex (i.e., both

[1] Aitken and Harrison (1999) also find negative spillover effects of FDI on the productivity of domestically owned plants in Venezuela.

[2] However, Keller (2009) argues that some issues such as a measurement problem in contractual payment between the MNEs and local firms may lead to estimation bias. Barrios, Gorg, and Strobl (2009) also argue that the measures of backward linkages used in recent studies on spillovers are potentially problematic. Using the standard measures employed in the literature, they fail to find robust evidence for spillovers through backward linkages. When they use alternative measures of backward linkages, on the other hand, they find robust evidence for positive FDI backward spillover effects.

[3] See Markusen (1995, 2002), Markusen and Maskus (2003), and Helpman (2006) for the survey of the literature.

horizontal and vertical) FDI arises endogenously. Grossman, Helpman, and Szeidl (2006) also analyze MNEs' integration strategies that may involve horizontal and vertical FDI simultaneously. A number of empirical studies give support to the predictions for horizontal FDI. For example, Brainard (1993, 1997) finds evidence of horizontal FDI but little evidence of vertical FDI. Markusen and Maskus (2002) argue that a large proportion of FDI is taken place among developed countries and is characterized by the horizontal type. Looking at the location decisions of MNEs, however, Yeaple (2003b) and Hanson, Mataloni, and Slaughter (2005) find evidence that is consistent with comparative advantage.

Alfaro and Charlton (2009) have recently shown that the share of vertical FDI is much higher than previously thought, even within developed countries. They argue that a significant amount of vertical FDI has been misclassified as horizontal in the previous studies. They find that a substantial amount of vertical FDI between developed countries emerge in high-skill sectors because parent firms own the stages of production proximate to their final production and source raw materials and inputs in low-skill production stages from outside of the firm.

Because most of the world's technology creation occurs in only a handful of developed countries, the pattern of worldwide technology changes is determined in large part by international technology spillovers (Keller, 2009). Consequently, the structure of MNEs' activity between developed countries may play a very important role in international technology spillovers.

Some recent studies have utilized patent citations data to investigate whether FDI plays any role in international technology spillovers.[4] In these studies, the term "technology spillovers" refers to "the process by which one inventor learns from the research outcomes of others' research projects and is able to enhance her own research productivity with this knowledge without fully compensating the other inventors for the value of this learning" (Branstetter, 2006: 327–328). Branstetter (2006) analyzes firm-level data of Japanese MNEs in the United States and patent citations at the US Patent and Trademark Office (USPTO) and finds evidence that FDI facilitates technology spillovers both from investing firms to local firms in the host country and from local firms to investing firms. Although he examine whether different types of FDI, such as acquisition, greenfield investment, and R&D facilities, have different effects on spillovers, he does not distinguish between horizontal and vertical FDI. Using patent citations data at the USPTO and the originally created parent-subsidiary database for MNEs investing in 30 countries, Singh (2007) also finds significant technology spillovers both from MNEs to the host country and from the host country to MNEs. In technologically advanced countries, knowledge outflows to foreign MNEs on average exceed knowledge inflows to the host country. Even in technologically less advanced countries, knowledge inflows from foreign MNEs to the host country are only slightly stronger than knowledge outflows. He does not distinguish among different types of

[4] In the literature, patent citations data are used as a proxy for spillovers of technological knowledge (Jaffe, Trajtenberg, and Henderson, 1993). There is a growing literature on empirical study of international technological spillovers based on patent citations (Jaffe and Trajtenberg, 1999; Hu and Jaffe, 2003; MacGarvie, 2006; Mancusi, 2008; Haruna, Jinji, and Zhang, 2010; Jinji, Zhang, and Haruna, 2010).

FDI.

In this paper, we attempt to combine a comprehensive firm-level dataset for the business activities of MNEs' foreign affiliates and information on the patent citations between MNEs and their host countries to identify how the structure of MNEs' activity in terms of horizontal and vertical FDI affects the technology spillovers between MNEs and host countries. Following Branstetter (2006), we define "technology spillovers" as the effects on the research productivity from the outcomes of others' research activities without full compensation for the value of research productivity enhancement.[5] We use firm-level data of Japanese firms' FDI and patent citations at the USPTO and Japanese Patent Office (JPO).[6] Our dataset includes information on the sales and purchases of the foreign affiliates, classified according to the destination and source countries. We exploit this information to construct new measures of horizontal and vertical FDI based on the shares of the host and home countries in their transactions. In particular, we define a measure of "pure horizontal FDI" as the extent to which affiliates' purchases of intermediate inputs and sales of final goods are concentrated in the local market. We also define a measure of "pure vertical FDI" as the extent to which affiliates' purchases of intermediate inputs and sales of final goods are linked to the home country. We can also define measures of "partially horizontal" and "partially vertical" FDI. We then estimate how different types of FDI affect technology spillovers from Japanese MNEs to the host country and from the host country to Japanese MNEs. As for the empirical methodology, we follow Branstetter (2006). Since the dependent variable (i.e., patent citations) is the count data, we utilize a negative binomial model developed by Hausman et al. (1984). Moreover, to deal with a potential endogeneity problem we also employ an endogenous switching model discussed by Miranda and Rabe-Hesketh (2006).

Our main findings are as follows. We find that an increase in the degree of pure vertical FDI has significantly positive effects on technology spillovers captured by patent citations when developed economies host Japanese MNEs. Spillovers occur in both directions between the MNEs and their host countries. These positive effects of pure vertical FDI on technology spillovers are robust for different specifications. Partially vertical FDI (i.e., FDI with a higher share of purchase of intermediate inputs in the local market and a higher share of sales of outputs to the home country) also has significantly positive effects on technology spillovers from the (high-income) host countries to the MNEs.[7] By contrast, an increase in the degree of pure horizontal FDI has no significant effect or significantly negative effects on technology spillovers between Japanese MNEs and their host countries. Partially

[5]Therefore, our definition of technology spillovers is narrower than that used in studies on the productivity change due to FDI or trade. However, we think that our definition is useful, because it focuses on direct effects and can still capture an important part of the effects in terms of the contribution to the expansion of the world's technology frontier.

[6]We acknowledge that the range of technology spillovers measured in the data may be narrowed, particularly for developing countries, by using patent citations, because many indigenous firms in developing countries are not so active in application of patents.

[7]The positive effects of partially vertical FDI are not robust when we employ different specifications, although we do not report the details of the estimated results in this paper.

horizontal FDI (i.e., FDI with a higher share of purchases from the home country and a higher share of sales to the local market) has significantly positive effects on technology spillovers from the MNEs to the (high-income) host countries, but the result is not robust for different estimations. We also find that when developing economies host Japanese MNEs, no form of FDI significantly facilitates technology spillovers between the MNEs and their host countries. In some estimations, partially vertical FDI has significantly positive effects on technology spillovers in both directions between the (low-income) host countries and the MNEs. However, the positive effects disappear when the possible endogeneity problem is controlled. From these results, we conclude that pure vertical FDI plays a dominant role in technology spillovers in both directions between Japanese MNEs and the high-income host countries.

Our findings have important policy implications. We find that the type of FDI matters for technology spillovers between MNEs and local firms in host countries. Therefore, whether or not government policies to attract inward FDI or to encourage outward FDI will successfully enhance technology spillovers from foreign to domestic firms depends on how parent firms organize the activities of their affiliates. However, it is not realistic for governments to tailor policies to attract only specific types of FDI. Since our results indicate that FDI with geographical fragmentation of production processes has positive effects on technology spillovers, policies to induce a harmonization of domestic product standards with international standards, for example, may be effective in promoting technology spillovers by facilitating inward investment by foreign firms.

The rest of the paper is organized as follows. Section 2 describes the data employed in our analysis. Section 3 introduces estimation methods. Section 4 provides empirical results. Section 5 concludes the paper.

2 Data

2.1 Data of patent citations and Japanese firms' FDI

Following Jaffe, Trajtenberg, and Henderson (1993), Jaffe and Trajtenberg (1999) and other studies, we use patent citations data as a proxy for technology spillovers. The patent citations are collected from the dataset compiled by the National Bureau of Economic Research (NBER) patent database for patents at the United States Patent and Trademark Office (USPTO). A new version of the NBER patent dataset has been extended to 2006.[8] This dataset includes the information on the application date, the country name of the assignee, the main US patent class, and citations made and received for each patent. From this dataset, we extract information on the patent applications and citations by the Japanese MNEs and their host countries. We also use the dataset released by the Japanese Institute of Intellectual Property (JIIP) for the patent applications at the Japanese Patent Office (JPO) from

[8]See the website of Bronwyn Hall for the new version of the NBER patent database.

1964 to 2008.[9] This dataset covers all information that corresponds to that of the NBER dataset for Japanese MNEs and their host countries. Because of the truncated problems of citations both in the datasets of the NBER and the JIIP, we concentrate our analysis on the period before 2003.

Our data for Japanese MNEs' activities abroad are obtained from the *Kaigai Jigyo Katsudo Kihon Chosa* (Survey on Overseas Business Activities, hereafter the METI survey) conducted by the Japanese Ministry of Economic, Trade and Industry (METI). This data source provides detailed data on affiliate-level FDI activities, such as the sales and purchases of affiliates of Japanese MNEs, classified by their destinations and sources, i.e., sales to (or purchases from) the local market, or exports to (or imports from) the home country and a third country.

The foreign affiliates listed in the METI survey are either foreign affiliates with at least 10% of their capital held by a Japanese parent company, or foreign affiliates with at least 50% of their capital held by a foreign subsidiary, which in turn has at least 50% of its capital held by a Japanese parent company. These affiliates exclude those that run businesses such as financial banking, insurance, or real estate in host countries. According to METI, there were approximately 15,000 foreign affiliates that responded to the survey in 2000.[10] Table 1 shows the top 30 host economies for Japanese MNEs in 2000, based on the number of affiliates that had completed the METI survey.[11] As shown in Table 1, the United States attracted the largest number of Japanese firms' affiliates, followed by China. Asian economies as well as developed countries are popular host economies for Japanese MNEs.

Our sample covers the period between 1995 and 2003. All countries in which Japanese MNEs have at least one affiliate are included in our sample. Since the countries vary significantly in terms of the number of patent applications made, we divide our sample into two groups according to the number of USPTO patent applications made by the sample countries during the period between 1995 and 2003. For Group I, the number of patent applications is larger than 1,000, while it is less than that for Group II.[12] All countries that are categorized into each group are listed in Table A1. Since Group I consists of high income countries/economies, we call Group I countries/economies "Developed Economies." In contrast, since the vast majority of countries/economies that are included into Group II are those in middle and low income countries, we call Group II countries/economies "Developing Economies."

We use the Nikkei company code system to link the three data sources and collected the data for 1,445 parent companies which run at least one affiliate during the sample period. Among these parent companies, 279 made at least one citation to USPTO patent applications from 93 countries, while

[9] See Goto and Motohashi (2007) for the details of JIIP dataset.

[10] See the website of METI (http://www.meti.go.jp/english/statistics/tyo/kaigaizi/index.html) for the details of the METI survey.

[11] About 10,100 affiliates reported full or partial information on their sales and purchases classified by the destinations and the sources in 2000.

[12] Although the number of USPTO patent applications made by China, India, Russia, and Singapore is more than 1,000 during the period, a large jump in applications is observed after 2000, compared with a very limited number in the early years for these countries. We therefore categorize those four countries into the second group.

393 parent companies made at least one citation to JPO patents. At the same time, 301 companies received at least one USPTO patent citation and 388 parent companies received at least one JPO patent citation.

Figure 1 shows the USPTO patent citations made (and received) by Japanese parent companies to (and from) developing economies, developed economies excluding the United States, and the United States in the sample period from 1995 to 2003. We take a logarithm of the average number of USPTO citations on the vertical axis. Looking at the number of patent citations for the three groups, we observe that most are made between Japanese parent companies and developed countries, compared with relatively smaller citations with developing countries. That is quite consistent with the argument in Keller (2009). If we use JPO patents, we can observe patterns that are similar to those in Figure 1. Note that, among the patent applications for USPTO patents in 2000, about 131,000 applications (44% of total applications) come from non-US residents, compared with 35,000 (8% of total applications) from non-Japanese residents for JPO patents.[13] Thus, patent citations collected from USPTO patents may provide more comprehensive information than those of the JPO patents.

2.2 Types of FDI

In the literature, FDI and MNEs' activities are usually categorized into horizontal and vertical. In the empirical studies, there are a number of ways to measure horizontal and vertical FDI.

Hummels, Ishii, and Yi (2001) and Alfaro and Charlton (2009) use the industrial classifications to define the types of FDI. Hanson, Mataloni, and Slaughter (2001, 2005) utilize the firm-level data from the US Bureau of Economic Analysis (BEA) to characterize vertical FDI as intra-firm flows of inputs which they observed flowing from parent companies in the United States to affiliates abroad. This method enables them to measure one-way US bilateral intra-firm trade. Using the same METI dataset as in this paper, Fukao and Wei (2008) employ the local sales ratio of the affiliates, and classify a local sales ratio that is less than the average ratio into vertical FDI and that larger than the average ratio into horizontal FDI.

An advantage of the METI survey dataset is that it allows us to measure vertical and horizontal FDI by using information on the sale of outputs and the purchase of inputs by foreign affiliates.[14] The local sales ratio and local purchases ratio of foreign affiliates of Japanese MNEs are denoted by $ShSaHFDI$ and $ShPuHFDI$, respectively. Similarly, the sales and purchases ratios to and from Japan for foreign affiliates of Japanese MNEs are denoted by $ShSaVFDI$ and $ShPuVFDI$, respectively. Table 2

[13] See the website of the World Intellectual Property Organization (http://www.wipo.int/portal/index.html.en) for the patent statistics of patent applications by the patent offices.

[14] One limitation of the METI survey dataset is, however, that it does not track transactions between foreign affiliates or between foreign affiliates and the parent companies. Thus, there may exist some biases for measuring the types of FDI by using information on sale and purchase because we cannot examine flows within the boundary of a firm from our dataset.

shows the average values of those ratios during the sample period for the subsamples of developed and developing economies. Looking at the ratios over the years, no evident trend is observed during the sample period. The table also interestingly shows that the values of $ShSaVFDI$, which indicates the vertical structure of sales from foreign affiliates, are around 10–12% in developed countries and around 20–22% in developing countries. If we focus on $ShPuVFDI$ (i.e., the vertical structure of purchases by foreign affiliates), on the other hand, the values are around 40–42% in developed countries and 37–40% in developing countries. Thus, in terms of the purchase of inputs, Japanese MNEs engage in vertical FDI more actively in developed host countries than in developing host countries. This evidence is consistent with Alfaro and Charlton (2009), who showed that vertical FDI emerges as far more prevalent between developed countries.

By exploiting information on the horizontal and vertical structures in sales and purchases of foreign affiliates, we construct new indexes of horizontal and vertical FDI, i.e., $HFDI$, $VFDI$, $PHFDI$, and $PVFDI$, in the following way:

$$\begin{aligned} HFDI &= ShSaHFDI \times ShPuHFDI \\ VFDI &= ShSaVFDI \times ShPuVFDI \\ PHFDI &= ShSaHFDI \times ShPuVFDI \\ PVFDI &= ShSaVFDI \times ShPuHFDI \end{aligned}$$

As is evident from the definition of the index, $HFDI$ measures the extent to which affiliates' purchases of intermediate inputs and sales of final goods are concentrated in the local market. Thus, $HFDI$ captures the degree of "pure" horizontal FDI. If $HFDI = 1$, a foreign affiliate makes all purchases and sales in the local market. However, if $HFDI = 0$, either or both of purchases and sales of a foreign affiliate are zero in the local market. Note that $HFDI = 0$ does not necessarily imply that the foreign affiliate engages in vertical activities because there is a possibility of transactions with third countries. $VFDI$ measures the extent to which affiliates' purchases of intermediate inputs and sales of final goods are linked to the home country (i.e., Japan). Thus, $VFDI$ captures the degree of "pure" vertical FDI. On the other hand, $PHFDI$ and $PVFDI$ capture "partially" horizontal and "partially" vertical FDI, respectively. The value of $PHFDI$ rises if an affiliate buys more intermediate goods from the home country and sells more final goods to the local market. Since the structure of sales is more important to distinguish the type of FDI than the structure of purchases, we consider that $PHFDI$ measures the degree of "partially" horizontal FDI due to its horizontal sales structure. Similarly, the value of $PVFDI$ becomes large if an affiliate buys more intermediate goods from the local market and sells more final goods to the home country. Since the structure of sales is vertical in $PVFDI$, we consider that it measures the degree of "partially" vertical FDI.

We then test whether there are any differences in the effects on technology spillovers among those types of FDI.

3 The Empirical Model

In this section, we explain our empirical model. Although the METI survey is conducted every year, there are many blanks in the data for a particular firm because in some years certain respondents did not report to METI. For this reason, we only use a pooled data in our estimation. Thus, we run the following specification as did in Branstetter (2006),

$$C_i = \beta_1 + \alpha_1 LPHost_i + \alpha_2 LPParent_i + \beta_2 FDI_i + u_i, \tag{1}$$

where i refers to the affiliate i, and C_i is the number of citations made (or received) by USPTO (or JPO) patents of the Japanese parent company that owns affiliate i. Note that $C_i = C_{i'}$ holds for affiliate i and affiliate i' if the same parent company owns affiliate i and affiliate i'. We expect that citations made by Japanese parent companies capture the technology spillovers flowing from the host countries to Japanese companies, while the citations received reflect the flows from Japanese companies to host countries. FDI_i is one of the alternative measures of the FDI types, i.e., $HFDI$, $VFDI$, $PHFDI$ and $PVFDI$ for affiliate i.

As indicated in Branstetter (2006), patent citations may rise as the "citable" host inventions increase. At the same time, the higher absorptive capacity in the home country may also be associated with a higher ability to understand and exploit external knowledge, and cite more external patents (Mancusi, 2008). Thus, we use $LPParent_i$ and $LPHost_i$, which refer to the logarithm of the count of the USPTO (or JPO) patent applications made by affiliate i's Japanese parent company and the host country where the affiliate i runs its business, respectively, to proxy the home absorptive capacity and "citable" host inventions. Note that $LPParent_i$ is the same across affiliate i for the same parent company, and $LPHost_i$ is the same across affiliate i for the same host country.

The focus of interest in (1) will be the coefficient β_2. That is, we examine if the types of FDI of Japanese firm in host countries have an influence on patent citations made and received by the firm. We also investigate if there is a difference in the magnitude and sign of the coefficient between the citations made and received by the home and host countries, and across the types of FDI Japanese firms implemented.

Since the observations of a dependent variable (i.e., patent citations) are the count data, we utilize a standard estimation technique, namely, a negative binomial model discussed in Cameron and Trivedi (1998), where the data are Poisson process, but more flexible modeling of the variance to account for overdispersion than the Poisson is allowed. We use this estimation technique to give our basic findings and alternative estimation results.

The other challenge of estimating the effects of the types of FDI on technology spillovers arises from the fact that patent citations may be endogenous in the sense that unobservables in determining the types of FDI may be correlated with unobservables in determining the citations. At the same time, certain geographic factors such as distance and language may influence the citations as well as the types of FDI. Neglecting these unobserved or endogenous factors may result in biased and inconsistent estimators.[15] We therefore attempt to use the endogenous switching model discussed in Miranda and Rabe-Hesketh (2006) in our empirical analysis. In that model, the citation C_i follows a Poisson distribution, and the probability distribution for count data is given by

$$Pr(C_i, \mu_i) = \frac{{\mu_i}^{C_i} \exp(-\mu_i)}{C_i!}, \tag{2}$$

so that a log-linear model for the mean of C_i, μ_i, can be specified as

$$\log(\mu_i) = \beta_1 + \alpha_1 LPHost_i + \alpha_2 LPParent_i + \alpha_3 LDist_i + \alpha_4 LGDP_i + \alpha_5 LCost_i + \beta_2 D_i + \epsilon_i, \tag{3}$$

where $LDist_i$ is the logarithm of the distance between Japan and the host economy of affiliate i, $LGDP_i$ is the logarithm of GDP of affiliate i's host economy, $LCost_i$ is the logarithm of salary per employee of affiliate i, and ϵ_i is an unobserved heterogeneity term. $LGDP_i$ measures the market size of the host economy and $LCost_i$ measures the labor cost of the affiliate. Instead of FDI_i in Eq. (1), here we use a dummy D_i (D_{HFDI_i}, D_{VFDI_i}, D_{PHFDI_i}, or D_{PVFDI_i}) for types of FDI, which equals one for a particular type, and zero otherwise. Following Fukao and Wei (2008), we construct the dummy for a particular type of FDI such that the dummy equals one when the value of an FDI type's index ($HFDI$, $VFDI$, $PHFDI$, or $PVFDI$) for affiliate i is greater than the average value of the particular FDI type's index in the full sample, and zero otherwise. We then use a probit model to examine how a parent firm determines its FDI type. The logic we use here is that the type decision of FDI depends on factors that favor a particular type of FDI or not. The probit model can be formulated as

$$D_i^* = z_i'\gamma + \lambda\epsilon_i + u_i, \tag{4}$$

and

$$D_i = \begin{cases} 1, & \text{if} \quad D_i^* > 0, \\ 0, & \text{otherwise,} \end{cases}$$

where z_i is a vector of factors which may influence the particular type of FDI. As usual, $u_i \sim N(0, 1)$ and u_i is independent of ϵ_i. In the so-called endogenous switching model, $Var(\epsilon_i) = \sigma^2$, and total variance is $\lambda^2\sigma^2 + 1$. If $\lambda = 0$, D_i is considered to be exogenous. Although a Poisson distribution is used, the variance of C_i is not necessarily equal to the conditional mean and overdispersion is allowed in this model. Using the normality assumption for ϵ_i, we have

$$Var(C_i|x_i, D_i) = E(C_i|\epsilon_i, x_i, D_i)[1 + E(C_i|\epsilon_i, x_i, D_i)(\exp(\sigma^2) - 1)],$$

where x_i is a vector of explanatory variables in Eq. (3) (i.e., $LPHost_i$, $LPParent_i$, $LDist_i$, $LGDP_i$, $LCost_i$, and the constant term), which implies that if $\sigma \neq 0$ the model exhibits overdispersion, as we would expect from the negative binomial model in Eq. (1). (See Miranda and Rabe-Hesketh (2006) for more detail.)

[15] See Kenkel and Terza (2001) and Wooldrige (2002) for treating with endogenous problems.

Using this approach, we expect that we could control endogenous factors that affect both technology spillovers and the structure of MNEs' activity. In the estimation, following Fukao and Wei (2008), we include $LDist_i$ (distance), $LGDP_i$ (market size), and $LCost_i$ (labor cost) in z_i in Eq. (4). Among those variables, the data for salaries and number of employees of foreign affiliates are obtained from the METI survey. The data on distance are measured as kilometers, and collected from the database of CEPII Research Center. Data on GDP in host countries are obtained from Penn World Tables.

Table A2 shows the descriptive statistics of variables. Table A3 shows the correlations among variables.

4 Empirical Results

In this section, we report our estimation results. We first show the basic findings by the negative binomial model. We then report the results by the endogenous switching model and discuss whether the endogeneity issue matters in our analysis. Finally, we discuss the robustness of our findings by showing the results of alternative estimations with additional explanatory variables. We also show the results using JPO patent data, in addition to USPTO data.

4.1 Basic findings

We first estimate Eq. (1) by the negative binomial model. The results are reported in Table 3. The upper panel of Table 3 shows the estimated results for the subsample of developed economies. We observe that the estimates of $HFDI$ are significant and negative, whereas they are significantly positive for $VFDI$, both for the citing and cited. As for $PHFDI$, the estimated coefficient is insignificant for the citing, and significantly positive for the cited. In contrast, the coefficient of $PVFDI$ reveals significant and positive for the citing and insignificant for the cited.

The lower panel of Table 3 presents the estimated results for the subsample of developing economies. Unlike the case of the developed economies, only the coefficients for $PVFDI$ show significantly positive, whereas the coefficients of the other types of FDI reveal negative or insignificant effects on the citing as well as the cited.

These results show that an increase in the degree of the "pure" vertical FDI has a significantly positive effect on technology spillovers in both directions between Japanese parent companies and their host countries if Japanese MNEs invest in high-income countries. This implies that vertical FDI may play a dominant role in technology spillovers with mutual effects in developed economies. When middle- and low-income countries host Japanese MNEs, on the other hand, an increase in the "partially" vertical FDI has a significantly positive effect on the number of patent citations in both directions between the Japanese parent companies and the firms in their host countries.

4.2 Estimating with an endogenous switching model

To deal with potential endogeneity issues, we simultaneously estimate an endogenous switching model described by Eqs. (2) and (3) for technology spillovers and a probit model based on Eq. (4) for the decision on FDI types. The estimated results are summarized in Tables 4 and 5. Table 4 shows the results for the subsample of developed economies and Table 5 shows those for the subsample of developing economies.

Columns 9 and 11 in Table 5 show that both of $LDist$ and $LGDP$ positively contribute to the choice of "pure" horizontal FDI (D_{HFDI}) and "partially" horizontal FDI (D_{PHFDI}) for the subsample of developing economies. As shown in columns 10 and 12 in Table 5, on the other hand, the coefficients of $LDist$ and $LCost$ turn out to be significantly negative for both "pure" vertical FDI (D_{VFDI}) and "partially" vertical FDI (D_{PVFDI}). These results are quite consistent with the findings in Fukao and Wei (2008). Thus, horizontal and vertical FDI to developing economies in our sample follow the standard theory of foreign investments and MNEs. By contrast, we observe different patterns for developed economies (Table 4). In particular, the coefficient of $LCost$ is significantly positive for both "pure" vertical FDI (D_{VFDI}) and "partially" vertical FDI (D_{PVFDI}). This implies that vertical FDI to developed economies is not motivated by wage cost saving.

In terms of the endogeneity between technology spillovers and the decision on FDI type, the estimates of ρ in the two tables imply strong significance against the null hypothesis in two cases out of eight estimations for developed economies and all cases for developing economies.[16] Thus, neglecting the endogenous issues may result in biased and inconsistent estimators (Miranda and Rabe-Hesketh, 2006). The estimations in Table 4 for developed economies reveal that D_{VFDI} based on the endogenous switching model for both the citing and cited cases provides results that are similar to those based on the negative binomial model. For D_{PVFDI}, the two models also provide similar results, suggesting that more local purchases and more sales in Japan may favor Japanese parents with more technology spillovers from the host economies. As observed for D_{HFDI} and D_{PHFDI}, the estimates turn insignificant or significantly negative for citing. Our findings imply that, for developed economies, "pure" vertical FDI is associated with significant technology spillovers, even controlling for endogenous issues. For developing economies, however, the estimated results of the switching model are insignificant or significantly negative for all types of FDI, suggesting no evidence of positive effects of FDI on technology spillovers between Japanese parent companies and developing host countries.

4.3 Alternative estimations

To check the robustness of the basic findings in Section 4.1, we conduct alternative estimations by adding explanatory variables. We include $PROX$ (technological proximity), $CapRatio$ (capital ratio), and $Close$ (a dummy for industrial classification, which is one for the same sector and zero otherwise).

[16] ρ is the correlation between ϵ_i and $\lambda\epsilon_i + u_i$ in (3), and $\rho = \lambda/\sqrt{2(\lambda^2+1)}$. ρ is identified by λ.

We also include $LDist$ (the logarithm of distance between Japan and host countries) and $Year$ which captures the changes in citations.

Japanese parent companies and firms in their host countries may increase their citations of each other just because Japanese parent companies and firms in their host countries change the focus of their research activities in ways that bring them "closer" to each other in the technology space (Branstetter, 2006). To control for this issue, we include a measure of technological proximity ($PROX$) in the regression. As suggested by Jaffe (1986) and Branstetter (2006), $PROX$ is constructed by

$$PROX_i = \frac{F_i F'_{host,i}}{[(F_i F'_i)(F_{host,i} F'_{host,i})]},$$

where $F_i = (f_{1i}, \cdots, f_{ki})$ is a vector of the cumulative count of patents obtained by affiliate i's parent firm in kth technical area[17] and $F_{host,i}$ is a vector of the aggregate count of patens obtained by all firms in the host country in which affiliate i is located.

The literature on the role of affiliate ownership in technology spillovers is limited. There are a few studies focused on the correlation between productivity and the ownership of affiliates. Javorcik (2004) and Javorcik and Spatareanu (2008) found that the correlation of productivity with FDI is stronger if the affiliate is only partially, and not fully foreign owned, because joint ownership generates more technology transfer, and wholly owned affiliates employ more sophisticated technology that is out of reach of the average domestic supplier. As indicated by Keller (2009), however, the technology gap may be a key reason for differential effects for wholly versus partially owned affiliates. $CapRatio$, which is the share of affiliate capital owned by Japanese parent, is included to test the effects of ownership of affiliates on technology spillovers.

As for the dependent variable, we use patent citations at the USPTO, just as in Section 4.1. We also use patent citations at the JPO for comparison. The correlations among explanatory variables and the USPTO citations are presented in Table A2. As in Section 4.1, we employ the negative binomial model for our estimation.

The estimated results are presented in Tables 6 to 9.[18] Table 6 (Table 7) shows the results for citations made (received) by Japanese parent firms to (from) the patents of host countries for the subsample of developed economies. In both Tables 6 and 7, the coefficients of $PROX$ are significantly positive in all cases of citing and cited. These results confirm the findings in Branstetter (2006). The dummy $Close$ reveals different effects on technology spillovers in the subsample of developed economies. The coefficients of $Close$ are significantly positive in technology spillovers from host economies to Japanese MNEs (Table 6), which implies that Japanese parent companies cite more patents of host economies when their affiliates run a business that is the same as or close to that of the parents. However, this is not the case for technology spillovers from Japanese MNEs to host economies

[17] We aggregate the US patent classes into 44 fields derived by Schmoch et al.(2003).

[18] Here, we only report the estimated results with full sets of explanatory variables. The results with various combinations of explanatory variables are available from the corresponding author upon request.

(Table 7), since the coefficients of *Close* are significantly negative in the case of patent citations at USPTO and are mostly insignificant in the case of patent citations at JPO. The ownership variable, *CapRatio*, has positive coefficients that are mostly significant, which implies that a higher share of ownership of foreign affiliates by Japanese parent companies tends to facilitate technology spillovers in both directions between Japanese MNEs and their host economies.

The estimates of $HFDI$, $VFDI$, $PHFDI$, and $PVFDI$ for USPTO give similar results to those we observed in Table 3, except for $PHFDI$ and $PVFDI$ in the cited. The estimates for JPO, on the other hand, indicate different results in many cases. Although we do not report the results in detail here, the significantly positive effect of $PVFDI$ is not robust for some combinations of explanatory variables.

Table 8 (Table 9) shows the results for citations made (received) by Japanese parent firms to (from) the patents of host countries for the subsample of developing economies. As in the case of developed economies, the coefficients of $PROX$ are significantly positive in all cases. The coefficients of *CapRatio* are significantly positive for the case of USPTO, which is consistent with the result for high-income host economies. However, in the case of citations at JPO, the coefficients of *CapRatio* are insignificant for the citing (Table 8) and significantly negative for the cited (Table 9). Thus, a higher share of foreign ownership may not always facilitate technology spillovers in developing economies. Moreover, the coefficients of *Close* are either insignificant or significantly negative in Tables 8 and 9, which suggests that when the host country is a developing economy, the closeness of industrial classification between parent companies and their foreign affiliates does not necessarily facilitate technology spillovers. It may even hinder technology spillovers.

The estimates of $HFDI$, $VFDI$, $PHFDI$, and $PVFDI$ in Tables 8 and 9 are basically consistent with those in Table 3. That is, the significantly positive coefficient is only for $PVFDI$, though the citing at the JPO does not confirm this.

5 Conclusions

In this paper, we have investigated how the structure of MNEs' activity affects technology spillovers between MNEs and their host countries by using detailed firm-level data of Japanese MNEs and patent citations data. We have proposed new specifications of FDI by using information on sales and purchases of foreign affiliates of MNEs. We define pure horizontal FDI as FDI with a high share of both purchase of intermediate inputs and sales of outputs in the local market. We also define pure vertical FDI as FDI with a high share of transactions (i.e., both purchases of intermediate inputs and sales of outputs) with the home country. Partially horizontal and partially vertical FDI are also defined.

We then found that when a developed country hosts Japanese MNEs, an increase in the degree of pure vertical FDI has a significantly positive effect on technology spillovers as measured by patent citations, in both directions between the host country and Japanese MNEs. In contrast, pure horizontal FDI has no significant effect or significantly negative effects on technology spillovers in either direction. It is clear that vertical FDI between developed countries is not based on factor price differentials. It may rather be motivated by utilizing technological advantage in the fragmented production process. If investing firms and local firms have a technological advantage at different stages of the production process, technology spillovers in both directions could occur by specializing in the production stage with technological advantages.

The results in this paper indicate that technology spillovers from FDI occur among developed economies. In particular, vertical FDI plays an important role in technology spillovers. Thus, developed countries can gain knowledge flow from MNEs' activities both as the home country and as the host country, when FDI involves the geographical fragmentation of the production process.

We also found that when the host country is a developing country, any types of FDI do not have positive effects on technology spillovers. One possible reason for this result is that we have focused on technology spillovers measured by patent citations. Since patent applications must be made to be counted as "spillovers," indigenous firms in developing countries may not strongly benefit from technology spillovers in our definition. Another possible interpretation of the result is that it reflects the stringency of intellectual property rights (IPRs) protection in host countries. Branstetter, Fisman, and Foley (2006) and Wakasugi and Ito (2009) find that the stronger protection of IPRs in host countries has a positive effect on technology transfer from parent firms to their foreign affiliates. Nagaoka (2009) also finds a positive effect of stronger patent protection on expanding the scope of the recipients of technology transfer. Taking these empirical findings into account, the weaker protection of IPRs in developing countries in general may hinder technology spillovers from FDI in our measurement.

Since our findings are based on Japanese MNEs' data, we suggest testing whether our findings could be applicable to other countries' MNEs by examining detailed data of MNEs in other countries.

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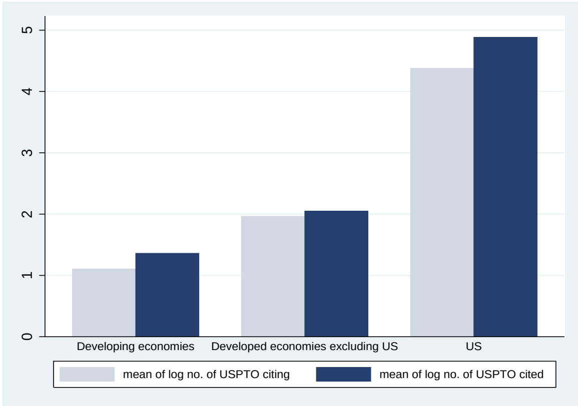

Source: The authors' calculation from the METI survey.

Figure 1: USPTO Citations for Japanese MNEs (1995–2003)

Table 1: Top 30 FDI Host Countries/Economies in 2000

Economy	No. of affiliates	Economy	No. of affiliates	Economy	No. of affiliates
United States	2,172	Australia	342	India	99
China	1,246	Korea	257	Vietnam	97
Thailand	692	Netherlands	248	Belgium	80
Singapore	613	France	216	New Zealand	74
Hong Kong	585	Canada	196	Chile	42
United Kingdom	509	Brazil	193		
Malaysia	477	Panama	138		
Taiwan	460	Mexico	132		
Indonesia	431	Italy	114		
Germany	363	Spain	100		

Note: The number of affiliates is those reported by respondents of the METI survey in 2000.

Table 2: Sales and Purchases Ratios of Affiliates Abroad

	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Developed Economies								
ShSaHFDI	0.761	0.747	0.735	0.757	0.761	0.759	0.751	0.752	0.745
ShSaVFDI	0.128	0.125	0.126	0.127	0.126	0.122	0.124	0.106	0.107
ShPuHFDI	0.530	0.493	0.474	0.501	0.481	0.481	0.490	0.464	0.462
ShPuVFDI	0.403	0.398	0.405	0.413	0.424	0.421	0.420	0.404	0.403
	Developing Economies								
ShSaHFDI	0.655	0.649	0.612	0.639	0.644	0.636	0.630	0.631	0.631
ShSaVFDI	0.208	0.197	0.211	0.222	0.212	0.212	0.228	0.204	0.208
ShPuHFDI	0.524	0.482	0.464	0.512	0.494	0.493	0.509	0.530	0.536
ShPuVFDI	0.392	0.395	0.401	0.405	0.407	0.402	0.403	0.370	0.369

Source: The authors' calculation from the METI survey data from 1995 to 2003.

Table 3: Negative Binomial Estimates for USPTO Citations

	Citing				Cited			
	Developed Economies							
HFDI	-0.172***				-0.480***			
	(-5.9)				(-10.2)			
VFDI		0.529***				1.273***		
		(6.2)				(8.4)		
PHFDI			-0.005				0.197***	
			(-0.2)				(4.4)	
PVFDI				0.115*				-0.120
				(1.8)				(-1.3)
LPHost	0.982***	0.976***	0.973***	0.973***	1.106***	1.087***	1.083***	1.081***
	(173.8)	(181.6)	(185.4)	(175.1)	(116.6)	(119.4)	(121.7)	(114.5)
LPParent	0.963***	0.963***	0.960***	0.966***	0.502***	0.503***	0.500***	0.506***
	(184.5)	(183.6)	(185.2)	(180.2)	(181.1)	(180.8)	(183.3)	(177.3)
No. of Obs	14836	14568	15441	14026	14836	14568	15441	14026
Log likelihood	-24646	-24059	-25682	-23157	-33957	-33306	-35403	-32028
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Developing Economies							
HFDI	-0.573***				-0.684***			
	(-5.1)				(-6.8)			
VFDI		0.189				0.182		
		(0.8)				(0.9)		
PHFDI			-0.033				-0.338***	
			(-0.3)				(-3.4)	
PVFDI				1.087***				0.938***
				(5.1)				(5.4)
LPHost	1.095***	1.085***	1.082***	1.081***	1.097***	1.112***	1.109***	1.088***
	(48.6)	(48.7)	(49.0)	(47.2)	(54.7)	(54.9)	(54.9)	(53.3)
LPParent	1.021***	1.018***	1.022***	1.037***	0.932***	0.934***	0.934***	0.949***
	(43.6)	(43.8)	(44.2)	(42.5)	(48.5)	(48.6)	(49.1)	(48.0)
No. of Obs	18928	18870	19345	18397	18928	18870	19345	18397
Log likelihood	-3836	-3917	-3988	-3755	-5732	-5795	-5919	-5604
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

Table 4: Endogenous Switching Estimates for USPTO Citations for Developed Economies

	Switching(citing)				Switching(cited)				D_{HFDI}	D_{VFDI}	D_{PHFDI}	D_{PVFDI}
D_{HFDI}	-0.084				-0.107							
	(-1.1)				(-1.3)							
D_{VFDI}		0.147***				0.509**						
		(8.6)				(2.3)						
D_{PHFDI}			-0.099***				0.062					
			(-11.0)				(1.3)					
D_{PVFDI}				0.151***				0.197				
				(2.8)				(1.5)				
$LPHost$	1.023***	1.020***	1.026***	1.018***	1.138***	1.134***	1.134***	1.133***				
	(147.9)	(153.2)	(175.4)	(158.6)	(116.8)	(126.2)	(129.2)	(122.4)				
$LPParent$	0.997***	0.999***	1.004***	0.999***	0.644***	0.647***	0.642***	0.649***				
	(169.4)	(187.5)	(256.1)	(167.2)	(96.9)	(96.9)	(98.7)	(95.5)				
$LDist$	-0.189***	-0.411***	-0.189***	-0.411***	-0.190***	-0.416***	-0.192***	-0.409***	-0.134***	-0.397***	0.006	-0.382***
	(-8.1)	(-13.8)	(-8.1)	(-13.8)	(-8.1)	(-13.6)	(-8.3)	(-13.6)	(-7.2)	(-16.0)	(0.3)	(-15.5)
$LGDP$	0.251***	0.047***	0.251***	0.047***	0.251***	0.047***	0.252***	0.047***	0.226***	0.061***	0.084***	0.028**
	(23.5)	(2.9)	(23.5)	(2.9)	(23.5)	(2.9)	(23.5)	(2.9)	(26.1)	(4.3)	(10.8)	(2.0)
$LCost$	-0.195***	0.094***	-0.195***	0.094***	-0.195***	0.094***	-0.194***	0.093***	-0.208***	0.095***	-0.172***	0.106***
	(-13.4)	(4.2)	(-13.4)	(4.2)	(-13.3)	(4.2)	(-13.3)	(4.2)	(-18.6)	(5.2)	(-16.0)	(5.8)
σ	0.651***	0.648***	0.658***	0.646***	1.487***	1.484***	1.483***	1.487***				
	(51.9)	(52.6)	(61.8)	(50.2)	(60.6)	(60.0)	(62.0)	(58.7)				
ρ	-0.013	0.058	-0.015	0.078	-0.020	-0.101 *	-0.082***	0.018				
	(-0.1)	(1.0)	(-0.4)	(1.1)	(-0.8)	(-1.8)	(-5.2)	(0.6)				
No. of Obs	35247	35247	35247	35247	35247	35247	35247	35247	17958	17776	18803	17014
Log likelihood	-31452	-39223	-25915	-24942	-33610	-32515	-40635	-32285	-10718	-3415	-12124	-3448
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

(4) D_{HFDI}, D_{VFDI}, D_{PHFDI} and D_{PVFDI} are dummy value for the four types of FDI.

Table 5: Endogenous Switching Estimates for USPTO Citations for Developing Economies

	Switching(citing)				Switching(cited)				D_{HFDI}	D_{VFDI}	D_{PHFDI}	D_{PVFDI}
D_{HFDI}	-1.028***				-0.880***							
	(-4.8)				(-3.2)							
D_{VFDI}		-0.825***				-1.473***						
		(-3.7)				(-5.3)						
D_{PHFDI}			-0.258**				-0.352 ***					
			(-2.3)				(-3.0)					
D_{PVFDI}				-0.589***				-0.180				
				(-3.6)				(-1.0)				
$LPHost$	1.190***	1.188 ***	1.193***	1.194***	1.214***	1.216***	1.224***	1.219***				
	(39.3)	(41.8)	(41.2)	(40.2)	(49.2)	(50.1)	(51.6)	(49.3)				
$LPParent$	1.161***	1.152***	1.164***	1.160***	1.023***	1.022***	1.030***	1.033***				
	(39.2)	(40.4)	(40.7)	(39.3)	(27.8)	(29.0)	(28.6)	(27.7)				
$LDist$	0.101***	-0.357***	0.097***	-0.359***	0.101***	-0.335***	0.097***	-0.358***	0.127***	-0.382***	0.245***	-0.353***
	(6.2)	(-17.0)	(6.0)	(-17.0)	(5.0)	(-12.5)	(4.9)	(-14.3)	(7.7)	(-15.3)	(15.2)	(-14.8)
$LGDP$	0.142***	-0.015	0.137***	-0.017*	0.143***	0.009	0.135***	-0.014	0.131***	-0.041***	0.110***	-0.072***
	(16.4)	(-1.5)	(16.2)	(-1.8)	(12.4)	(0.7)	(13.2)	(-1.2)	(17.8)	(-4.4)	(15.4)	(-7.8)
$LCost$	0.047***	-0.203***	0.048***	-0.203***	0.047***	-0.197***	0.049***	-0.203***	0.035***	-0.214***	0.031***	-0.183***
	(7.2)	(-26.9)	(7.5)	(-27.1)	(6.2)	(-18.8)	(6.3)	(-21.7)	(5.2)	(-27.3)	(4.7)	(-23.8)
σ	1.400***	1.423***	1.373***	1.417***	1.506***	1.640***	1.488***	1.531***				
	(22.4)	(24.2)	(22.9)	(22.6)	(33.5)	(26.7)	(34.7)	(34.7)				
ρ	0.273***	0.438***	-0.098**	0.331***	0.166*	0.703***	-0.101***	0.243***				
	(3.7)	(7.3)	(-2.3)	(6.5)	(1.9)	(17.3)	(-2.7)	(5.2)				
No. of Obs	41080	41080	41080	41080	41080	41080	41080	41080	24590	24747	25390	23894
Log likelihood	-13354	-9916	-13507	-9762	-15279	-11801	-15457	-11642	-14992	-9438	-16029	-9905
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

(4) D_{HFDI}, D_{VFDI}, D_{PHFDI} and D_{PVFDI} are dummy value for the four types of FDI.

Table 6: Alternative Estimations for Citations Made by MNEs to Developed Economies

	USPTO	JPO	USPTO	JPO	USPTO	JPO	USPTO	JPO
$HFDI$	-0.125***	-0.064*						
	(-4.0)	(-2.0)						
$VFDI$			0.387***	0.251**				
			(4.0)	(2.3)				
$PHFDI$					-0.026	0.079***		
					(-0.9)	(2.6)		
$PVFDI$							0.151**	0.175***
							(2.1)	(2.6)
$LPHost$	0.937***	1.036***	0.935***	1.039***	0.930***	1.033***	0.933***	1.035***
	(138.9)	(96.0)	(144.5)	(98.6)	(148.2)	(101.6)	(140.1)	(95.5)
$LPParent$	0.944 ***	0.876***	0.944***	0.883***	0.939***	0.878***	0.945***	0.884***
	(153.9)	(124.3)	(153.5)	(124.0)	(154.8)	(126.5)	(150.7)	(121.6)
$PROX$	0.904***	1.863***	0.903***	1.828***	0.963***	1.907***	0.926***	1.828***
	(13.6)	(29.1)	(13.4)	(28.2)	(14.8)	(30.4)	(13.6)	(27.7)
$CapRatio$	0.270***	0.245***	0.222***	0.230***	0.295***	0.226***	0.287***	0.257***
	(4.4)	(3.7)	(3.6)	(3.5)	(4.9)	(3.5)	(4.6)	(3.8)
$Close$	0.075***	0.060**	0.069***	0.053**	0.070***	0.054**	0.067***	0.063**
	(3.3)	(2.5)	(3.0)	(2.2)	(3.1)	(2.3)	(2.9)	(2.5)
$LDist$	0.140***	0.206***	0.158***	0.210***	0.142***	0.209***	0.129***	0.192***
	(5.4)	(8.1)	(5.8)	(7.9)	(5.5)	(8.4)	(4.9)	(7.5)
$Year$	0.000	-0.045***	0.003	-0.042***	-0.001	-0.046***	0.001	-0.042***
	(0.0)	(-10.6)	(0.6)	(-9.8)	(-0.2)	(-11.2)	(0.3)	(-9.6)
No. of Obs.	6505	10539	6330	10297	6835	10961	6047	9914
Log likelihood	-20903	-20251	-20335	-19798	-21692	-20985	-19616	-19068
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

Table 7: Alternative Estimations for Citations Received by MNEs from Developed Economies

	USPTO	JPO	USPTO	JPO	USPTO	JPO	USPTO	JPO
$HFDI$	-0.126**	-0.110***						
	(-2.4)	(-3.0)						
$VFDI$			0.438***	0.212				
			(2.6)	(1.6)				
$PHFDI$					-0.228***	-0.012		
					(-4.8)	(-0.4)		
$PVFDI$							0.298**	-0.069
							(2.4)	(-0.9)
$LPHost$	1.001***	0.988***	0.997***	0.999***	0.998***	0.983***	0.996***	0.985***
	(91.7)	(86.6)	(95.4)	(85.1)	(98.3)	(90.8)	(92.6)	(85.2)
$LPParent$	0.362***	0.873***	0.361***	0.843***	0.358***	0.869***	0.363***	0.878***
	(87.7)	(117.5)	(86.3)	(108.5)	(88.6)	(119.6)	(84.9)	(114.5)
$PROX$	2.962***	3.178***	2.983***	2.959***	3.008***	3.164***	2.992***	3.226***
	(25.0)	(46.2)	(24.8)	(39.9)	(26.0)	(46.7)	(24.5)	(45.6)
$CapRatio$	0.162	0.175**	0.150	0.200***	0.249***	0.242***	0.156	0.216***
	(1.6)	(2.4)	(1.5)	(2.6)	(2.6)	(3.4)	(1.5)	(2.9)
$Close$	-0.272***	0.006	-0.307***	0.062**	-0.298***	-0.008	-0.284***	-0.017
	(-7.3)	(0.2)	(-8.1)	(2.1)	(-8.1)	(-0.3)	(-7.3)	(-0.6)
$LDist$	0.154***	-0.287***	0.190***	-0.243***	0.148***	-0.304***	0.164***	-0.282***
	(3.9)	(-11.0)	(4.7)	(-8.7)	(3.8)	(-11.8)	(4.1)	(-10.6)
$Year$	0.072***	0.031***	0.082***	0.060***	0.076***	0.031***	0.077***	0.034***
	(10.1)	(6.6)	(11.4)	(12.1)	(11.0)	(6.7)	(10.5)	(6.9)
No. of Obs.	6505	10539	6330	10297	6835	10961	6047	9914
Log likelihood	-27042	-23844	-26400	-23826	-28068	-24796	-25420	-22478
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

Table 8: Alternative Estimations for Citations Made by MNEs to Developing Economies

	USPTO	JPO	USPTO	JPO	USPTO	JPO	USPTO	JPO
$HFDI$	-0.108	0.018						
	(-1.0)	(0.2)						
$VFDI$			0.197	-0.500				
			(0.9)	(-2.0)				
$PHFDI$					-0.163*	0.163		
					(-1.7)	(1.4)		
$PVFDI$							0.968***	-0.322
							(5.5)	(-1.6)
$LPHost$	0.906 ***	0.705***	0.921***	0.692***	0.917***	0.690***	0.916***	0.701***
	(35.8)	(19.9)	(36.3)	(19.5)	(36.5)	(19.6)	(35.9)	(19.5)
$LPParent$	0.885***	0.764***	0.885***	0.766***	0.890***	0.770***	0.892***	0.764***
	(39.7)	(30.5)	(39.9)	(30.3)	(40.4)	(30.7)	(39.3)	(29.9)
$PROX$	2.524***	2.859***	2.454***	2.876***	2.474***	2.870***	2.519***	2.877***
	(19.7)	(16.4)	(19.2)	(16.5)	(19.6)	(16.7)	(19.5)	(16.3)
$CapRatio$	0.663***	0.202	0.712***	0.284*	0.701***	0.207	0.614***	0.243
	(4.5)	(1.3)	(5.0)	(1.8)	(5.1)	(1.4)	(4.3)	(1.5)
$Close$	-0.109	-0.079	-0.132*	-0.076	-0.130*	-0.065	-0.145*	-0.080
	(-1.5)	(-1.0)	(-1.8)	(-0.9)	(-1.8)	(-0.8)	(-1.9)	(-1.0)
$LDist$	-0.262 ***	-0.441***	-0.207***	-0.476***	-0.234***	-0.443***	-0.183***	-0.468***
	(-3.3)	(-3.8)	(-2.6)	(-4.0)	(-3.0)	(-3.9)	(-2.2)	(-3.9)
$Year$	-0.010	-0.109***	-0.011***	-0.105***	-0.017	-0.105***	-0.008	-0.106***
	(-0.7)	(-7.0)	(-0.7)	(-6.8)	(-1.1)	(-6.9)	(-0.5)	(-6.7)
No. of Obs.	7156	12740	7086	12682	7329	13001	6904	12375
Log likelihood	-3242	-2298	-3287	-2284	-3343	-2344	-3157	-2231
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

Table 9: Alternative Estimations for Citations Received by MNEs from Developing Economies

	USPTO	JPO	USPTO	JPO	USPTO	JPO	USPTO	JPO
$HFDI$	-0.469***	-0.040						
	(-4.3)	(-0.5)						
$VFDI$			0.307	0.102				
			(1.4)	(0.6)				
$PHFDI$					-0.294***	0.086		
					(-3.0)	(1.1)		
$PVFDI$							1.038***	0.504***
							(6.4)	(3.8)
$LPHost$	1.021***	1.049***	1.041***	1.068***	1.034***	1.045***	1.027***	1.065***
	(42.2)	(41.0)	(42.4)	(41.3)	(42.7)	(41.1)	(42.4)	(41.1)
$LPParent$	0.825***	0.799***	0.827***	0.784***	0.828***	0.803***	0.838***	0.795***
	(40.4)	(54.3)	(40.2)	(52.8)	(41.0)	(54.3)	(40.6)	(53.3)
$PROX$	2.705***	2.297***	2.687***	2.334***	2.686***	2.308***	2.723***	2.321***
	(21.1)	(19.7)	(20.7)	(19.9)	(21.1)	(19.9)	(21.2)	(19.8)
$CapRatio$	0.800***	-0.328***	0.981***	-0.346***	0.995***	-0.331***	0.822***	-0.359***
	(5.5)	(-2.9)	(7.0)	(-3.2)	(7.3)	(-3.1)	(5.9)	(-3.3)
$Close$	0.037	-0.362***	0.030	-0.331***	-0.007	-0.340***	-0.042	-0.355***
	(0.5)	(-6.5)	(0.4)	(-6.0)	(-0.1)	(-6.2)	(-0.6)	(-6.4)
$LDist$	0.139*	-0.302***	0.141*	-0.261***	0.115	-0.288***	0.218***	-0.272***
	(1.9)	(-4.4)	(1.9)	(-3.6)	(1.6)	(-4.2)	(2.9)	(-3.8)
$Year$	0.062***	0.148***	0.057***	0.145***	0.048***	0.148***	0.054***	0.139***
	(4.2)	(12.5)	(3.9)	(12.3)	(3.3)	(12.7)	(3.6)	(11.7)
No. of Obs.	7156	12740	7086	12682	7329	13001	6904	12375
Log likelihood	-4604	-5655	-4621	-5644	-4730	-5746	-4464	-5474
Prob>chi^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: (1) "***," "**" and "*" denote 1%, 5% and 10% significant level.

(2) The values in the parentheses are t-statistics.

(3) Constant terms are included in the estimations.

Table A1: List of Countries/Economies

Group I (Developed Economies)	Group II (Developing Economies)			
Australia	Argentina	Ghana	Niger	Trinidad&Tobago
Austria	Bahamas	Greece	Nigeria	Tunisia
Belgium	Bahrain	Guatemala	Pakistan	Turkey
Canada	Bangladesh	Hong Kong	Panama	United Arab Emirates
Denmark	Bolivia	Hungary	Papua New Guinea	Uruguay
Finland	Brazil	Iceland	Paraguay	Venezuela
France	Brunei	India	Peru	Vietnam
Germany	Cambodia	Indonesia	Poland	Zambia
Israel	Cameroon	Iran	Portugal	Zimbabwe
Italy	Chile	Ireland	Qatar	
Korea, Republic of	China	Jamaica	Romania	
Luxembourg	Colombia	Kenya	Russia	
Netherlands	Costa Rica	Kuwait	Samoa	
New Zealand	Cyprus	Laos	Saudi Arabia	
Norway	Czech	Lebanon	Senegal	
Spain	Dominican	Liberia	Singapore	
Sweden	Ecuador	Macao	Slovak	
Switzerland	Egypt	Madagascar	South Africa	
Taiwan	El Salvador	Malaysia	Sri Lanka	
United Kingdom	Ethiopia	Mexico	Tanzania	
United States	Fiji	Morocco	Thailand	

Table A2: Descriptive Statistics

Variable	Obs	Mean	Std.Dev	Min	Max
	Developed Economies				
USPTO Citing	50736	74.92	463.73	0	7039
USPTO Cited	50736	190.20	1052.32	0	13484
JPO Citing	50736	13.00	60.67	0	813
JPO Cited	50736	24.58	122.04	0	1806
$HFDI$	20872	0.34	0.38	0.00	1.00
$VFDI$	20623	0.02	0.10	0.00	1.00
$PHFDI$	21757	0.33	0.36	0.00	1.00
$PVFDI$	19798	0.07	0.21	0.00	1.00
$LPHost$(USPTO)	50736	6.36	7.27	-9.21	12.09
$LPParent$(USPTO)	50736	-4.38	6.53	-9.21	8.16
$PROX$(USPTO)	24480	0.37	0.19	0.00	0.96
$LPHost$(JPO)	50736	8.43	1.67	3.22	10.12
$LPParent$(JPO)	50736	0.41	6.80	-9.21	9.62
$PROX$(JPO)	39060	0.39	0.20	0.00	0.94
$CapRatio$	45262	0.90	0.22	0.00	1.00
$Close$	50736	0.40	0.49	0.00	1.00
$LDist$	50736	9.09	0.50	7.05	9.29
$LCost$	25901	1.63	0.97	-5.54	9.53
$LGDP$	50736	21.75	1.36	18.07	23.27
	Developing Economies				
USPTO Citing	63445	0.39	5.59	0	218
USPTO Cited	63445	0.91	11.85	0	444
JPO Citing	63445	0.06	0.53	0	20
JPO Cited	63445	0.66	7.10	0	244
$HFDI$	28664	0.33	0.37	0.00	1.00
$VFDI$	28834	0.08	0.20	0.00	1.00
$PHFDI$	29494	0.23	0.31	0.00	1.00
$PVFDI$	27914	0.10	0.22	0.00	1.00
$LPHost$(USPTO)	63445	-0.34	6.50	-9.21	8.58
$LPParent$(USPTO)	63445	-5.22	6.25	-9.21	8.16
$PROX$(USPTO)	26312	0.29	0.24	0.00	0.99
$LPHost$(JPO)	63445	2.72	3.77	-9.21	7.53
$LPParent$(JPO)	63445	-0.37	7.02	-9.21	9.62
$PROX$(JPO)	45431	0.35	0.22	0.00	0.96
$CapRatio$	57244	0.76	0.28	0.00	1.00
$Close$	63445	0.47	0.50	0.00	1.00
$LDist$	63445	8.35	0.64	7.65	9.83
$LCost$	34377	-0.21	1.45	-8.65	7.94
$LGDP$	63445	20.26	1.64	12.62	23.00

Table A3: Correlations for the Variables

	Citing (USPTO)	Cited (USPTO)	*HFDI*	*VFDI*	*PHFDI*	*PVFDI*	*LPHost* (USPTO)	*LPParent* (USPTO)	*PROX*	*CapRatio*	*Close*	*LDist*
Citing (USPTO)	1.00											
Cited (USPTO)	0.82	1.00										
HFDI	0.04	0.04	1.00									
VFDI	-0.01	-0.02	-0.23	1.00								
PHFDI	0.01	0.03	-0.36	-0.14	1.00							
PVFDI	0.00	-0.01	-0.13	0.17	-0.27	1.00						
LPHost(USPTO)	0.17	0.18	0.06	-0.05	0.11	-0.03	1.00					
LPParent(USPTO)	0.16	0.15	0.00	-0.01	0.02	-0.04	0.64	1.00				
PROX	0.15	0.18	-0.01	-0.01	0.01	0.01	0.16	0.09	1.00			
CapRatio	0.05	0.06	-0.25	0.05	0.07	0.01	0.06	-0.04	0.14	1.00		
Close	-0.05	-0.05	0.11	0.02	-0.09	0.07	-0.07	-0.14	-0.09	-0.11	1.00	
LDist	0.13	0.15	-0.01	-0.23	0.06	-0.15	0.17	0.07	0.05	0.33	-0.07	1.00