Technological Capability and Foreign Direct Investment in Asia: Firm-level Relationship in Japanese Manufacturers

(This version is before the referee review process.)

January 26, 2004

Eiichi Tomiura
Research Institute for Economics and Business Administration, Kobe University,
2-1 Rokko-dai, Nada-ku, Kobe City 657-8501 JAPAN.

Phone: +81-78-803-7008. Fax: +81-78-803-7059.

E-mail: tomiura@rieb.kobe-u.ac.jp.

Technological Capability and Foreign Direct Investment in Asia: Firm-level Relationship in Japanese Manufacturers

Abstract

This paper reexamines the relationship between FDI and R&D by exploiting firm-level data for 118,300 Japanese manufacturers with no threshold. Our study confirms that higher technological capability is positively related with more extensive FDI even if firms with no FDI or R&D are included into regressions. This relation with R&D is stronger for FDI in industrial countries than in Asia, and especially evident for FDI in industrial countries by firms that have invested in Asia. This paper also finds that firms with richer human skills tend to prefer majority ownership in FDI, as consistent with the internalization FDI theory.

Keywords: R&D; foreign direct investment; Asia; ownership; firm-level data

JEL Classifications: F23; L22

I. Introduction

As described in Caves (1996), accumulated evidence has shown that the intensity of research and development (R&D) is positively related with foreign direct investment (FDI).[1] However, previous studies of Japanese FDI, such as Belderbos and Sleuwaegen (1996) and Fukao et al. (1994) based on the 1980s data, found that R&D of a firm tends to have a positive effect on the firm's FDI in industrial countries, but *no* significant effect on FDI in Asia.[2] Recent dramatic development of Asian economies induces us to reexamine this issue with more recent data because FDI in Asia may now require Japanese firms to have high technological capability.

One of the novelties of this paper is the comprehensiveness of the data, as our estimation is based on previously unavailable firm-level data, derived from a survey for more than 118 thousand Japanese manufacturers without any firm-size threshold covering all industries. The survey's wide coverage and large sample size ensure that it provides an accurate overall representation of manufacturing firms. Both R&D and FDI data are consistently drawn from the same survey. Utilizing firm-level data, this paper investigates not only whether FDI in Asia is positively related with the firm's R&D, but also whether or not the relationship between R&D and FDI in industrial countries is affected by the firm's experience with FDI in Asia.

Although previous literature has contributed immensely to our understanding of FDI, they often depend on FDI data, which limit our focus to the comparison of firms that have already invested in foreign countries.[3] However, since the vast majority of firms have no foreign affiliates at all, and since firms not investing abroad at all are on average as R&D active as firms investing abroad, we need to investigate a comprehensive sample including firms with

[1] Caves (1996) and UNCTC (1992) describe R&D as one of the strongest determinants of FDI among firm characteristics, such as advertising, skilled managerial labor, and multi-plant operation.
[2] To the knowledge of the author, within papers published in international academic journals, there exists no recent paper on the relation between Japanese FDI and R&D. As a related topic, Okabe (2003) empirically analyses R&D and technology importation in aggregated Japanese industries.
[3] As an exceptional previous study, Belderbos and Sleuwaegen (1996) include 65 no-FDI firms in their analysis of the firm's choice among domestic, FDI in West, and FDI in Asia.

no FDI. As the inclusion of such domestic firms may attenuate the impact of R&D on FDI, this paper examines whether or not the sample selectivity significantly affects the robustness of the positive association between FDI and technological capability.

Besides, inspired by recent empirical studies of FDI, such as Asiedu and Esfahani (2001) and Barbosa and Louri (2002), this paper also investigates the relationship between the R&D of a firm and the firm's FDI ownership structure preferences. The difficulty in defining and monitoring the proprietary rights associated with intangible assets induces firms to prefer majority ownership shares in FDI in order to securely internalize the gains from these costly-to-market assets. Consequently, this paper examines whether or not the effect of R&D on FDI is stronger for majority-owned FDI than for minority-owned FDI. Using firm-level characteristics included in our dataset, this paper also evaluates the impact of management skills, which is another intangible asset as important as technology capital accumulated by R&D spending, on the ownership structure of FDI.

The rest of this paper is organized as follows. Section II describes our data. Section III explains empirical specifications and estimation methods. Section IV reports empirical results. Section V concludes.

II. Description of Data

All the data used for this paper are derived from the firm-level data of *the Basic Survey of Commercial and Manufacturing Structure and Activity* (Sho-Kogyo Jittai Kihon Chosa in Japanese).[4] This survey, including firms of all sizes and in all manufacturing industries, contains a range of data on firm characteristics at 1998, such as sales, capital, R&D spending,

4 This paper focuses on manufacturing firms by excluding commercial firms.

and industry classification.[5] The survey captures FDI in the number of foreign subsidiaries/affiliates for each firm, although no data is available for FDI size.[6] Regarding regional destinations of FDI, Asia is considered separately from the rest of the world.[7] Regarding ownership structure, the survey identifies foreign subsidiaries with majority ownership (kogaisha in Japanese) and those with holding shares of no less than 20 percent but no more than 50 percent (kanrengaisha in Japanese).[8] A large number of firms with no FDI or no R&D at all are included in our sample of 118,300 manufacturers. The survey's large size and wide coverage ensures that it provides an accurate overall representation of manufacturing in Japan. The published aggregate data from this survey confirm the relatively strong positive correlation between R&D intensity (R&D spending divided by sales) and FDI at the industry-level.[9] Averaging over heterogeneous firms, however, inevitably contaminates industry-level values.

Table 1 classifies firms by whether or not the firm is involved in R&D or FDI.[10] Noteworthy findings from our micro-data are as follows. Here, we will refer to firms with strictly positive FDI (R&D) as "FDI firms" ("R&D firms") and to firms with zero FDI (R&D) as "no-FDI firms" ("no-R&D firms"), respectively.[11]

First, as shown in (A) of Table 1, only two percent of 118,300 firms in our sample

---

5 Although it contains similar data, the *Basic Survey of Business Structure and Activities* (Kigyo Katsudo Kihon Chosa in Japanese) covers only limited numbers of large firms (defined as those with more than fifty employees and capital of more than thirty million yen).

6 Sales branch offices are not distinguished from manufacturing affiliates in the survey.

7 "Asia" in this survey includes not only ASEAN, but also countries such as China and India.

8 Foreign offices with ownership less than 20% are not recognized with destination disaggregation.

9 The correlation between the percentage R&D intensity and the industry's share in total number of foreign subsidiaries is 0.731 among two-digit industries.

10 Since all the firms with no response to questions on R&D spending values and on FDI counts explicitly answered that they conduct no R&D and no FDI at all in the binary question, we treat them as zero.

11 Although the survey is collected from parent firms, R&D figures could include R&D expenditures by foreign subsidiaries. However, overseas R&D has been practically limited in Japanese firms.

undertake both R&D and FDI. Even if we include no-R&D firms, the share of FDI firms is merely around three percent of all firms.[12] This implies that previous studies based on samples solely from FDI firms do not replicate the whole manufacturing at all. On the other hand, nearly 17 percent of firms conduct R&D.[13] The share of R&D firms is substantially higher among FDI firms, compared with among no-FDI firms (66%>15%). By covering these no-FDI firms and no-R&D firms, our sample is suited for evaluating the impact of R&D on FDI decision in the universe of all firms.

Second, as reported in (B), R&D firms appear more active in FDI than no-R&D firms in all categories of FDI, irrespective of destination and ownership structure.[14] Since most FDI by Japanese firms go either into Asia, U.S., or E.U. regions, and since no further regional disaggregation is available in the survey, let us approximately interpret the rest of the world other than Asia as industrial countries.[15] The contrast between R&D firms and no-R&D firms is particularly evident in FDI with majority ownership in industrial countries.

Third, however, among firms undertaking positive R&D, the average R&D intensity of FDI firms is approximately the same as that of no-FDI firms, as demonstrated in (C). This observation indicates that previous results based only on FDI firms may overestimate the magnitude of the effect of R&D on FDI. Consequently, this paper examines in the next section whether or not this sample selectivity is significant by including no-R&D firms as well as no-FDI firms into regressions.

Finally, as shown in (D) of Table 1, while the average R&D firm is five to seven times

---

12 Since the firms whose employees are less than fifty are sampled with probability less than one, the share of FDI firms in the whole population must be even lower. Although the government does not disclose the rescaling method for sampling probability, the published aggregate statistics from the same survey reports that 1.5% of manufacturers have foreign subsidiaries.
13 According to the published aggregated statistics, only 12% of manufacturers conduct any R&D.
14 This kind of cross-aggregation is not released in the published aggregated statistics.
15 A recent figure from FDI statistics by the Ministry of Finance, for example, shows that 87% of aggregate Japanese FDI into non-Asian countries is either in U.S., Europe, or Oceania.

larger than the average no-R&D firm, the average FDI firm is 14 to 21 times larger than the average no-FDI firm in terms of sales. This may suggest some forms of fixed sunk entry costs associated with R&D and FDI, especially with FDI. This implied difference in fixed costs between FDI and R&D is also consistent with our previous finding of the asymmetry that the share of FDI firms is much lower than that of R&D firms in the total number of firms.

III. Empirical Models

This section explains the empirical models for this paper. The basic specification relating FDI with R&D intensity, as a reduced form, is as follows.

$$FDI_i = \alpha + \beta_1 \ln\left(1 + \frac{R\&D_i}{Q_i}\right) + \beta_2 \ln Q_i + \beta_3 \ln\frac{K_i}{Q_i} + \beta_4 \ln HS_i + \gamma DUM + u_i \,. \quad (1)$$

The suffix *i* indexes the firm. *FDI* denotes foreign direct investment either in Asia or industrial countries, either with majority ownership or minority ownership. The variables *Q*, *K*, *HS*, and *R&D* are the output (sales), the capital (tangible fixed asset), the human skill intensity (measured by per-capita overhead non-production expenditure), and the R&D spending, respectively.[16] The vector of industry dummy variables is expressed by *DUM*.[17] The error term is denoted by *u*. Adding one to R&D intensity before taking logarithm substantially increases the numbers of observations available for regressions, since more than eighty percent of firms in our sample have zero R&D.[18] Although this specification is flexible in incorporating a wide range of control variables, we should not interpret the results as suggesting that more active

16 Since the survey contains no data directly related with wage, this paper uses the selling, general and administrative pay (SGA) divided by the number of employees for the index of skill intensity. Data of advertising expenditure and business group affiliations are not available in the survey.

17 The two-digit classification is used, since including dummies for all three-digit industries considerably loses the degree of freedom in regressions.

18 R&D is measured in flow (spending during the previous year), while FDI is in stock terms (number of foreign subsidiaries). To overcome this inconsistency, we will later use patent data.

R&D causes more extensive FDI because they are simultaneously determined.[19]

According to the standard theory of FDI, as surveyed by Caves (1996) for example, a firm invests directly in foreign countries if the firm has advantage, compared with local rival firms, in intangible assets, such as technology or human capital. Unless a firm possesses these assets costly to transact at arm's length, the firm is not likely to establish their own subsidiaries in foreign countries.[20] Taking account of the technology gap between developed and developing countries, we expect that more active R&D is required for firms directly investing in industrial countries, compared with Asia.[21] Similarly, regarding ownership structure, FDI with majority ownership, rather than FDI with minority ownership, is expected to more strongly relate with R&D because the gains from intangible assets are not easily traded in markets.[22] Since human capital is also suited for internalization, the coefficient on *HS* is expected larger for FDI in industrial countries than FDI in Asia, and for majority-owned FDI than minority-owned FDI. On the other hand, the firm size is expected to have positive effect on FDI in any region and with any ownership structures because FDI incurs fixed sunk costs for establishing subsidiaries. The capital-output ratio is supposed to act as an inverse proxy for richness in intangible assets.[23]

This paper conducts robustness checks by using various alternative estimation methods and alternative ranges of data. First, this paper estimates (1) by OLS over the sample of firms with FDI and R&D both strictly positive. This can be served as the benchmark of our analysis, comparable with previous studies. Second, taking account that our FDI measure is a limited

---

19 Since we depend on a cross-section data as in many previous studies of FDI, finding appropriate instrumental variables is practically difficult.

20 Host country factors are not considered here due to the limit of data availability.

21 If the FDI competition among various industrial countries is intense, this difference depending on destination is not obvious. However, no such data is available in our survey of Japanese firms.

22 Asiedu and Esfahani (2001) and Barbosa and Louri (2002) focused on the effect on the ownership choice of individual FDI project, based on affiliate data. This approach should be viewed as complementary to ours.

23 When direct R&D data are not available, as in Asiedu and Esfahani (2001), the capital-output ratio is used in this context, while we simultaneously include R&D and human skill intensity.

dependent variable, this paper estimates the equation not only by OLS, but also by Poisson, negative binomial regressions, or Tobit.[24] Third, this paper replaces R&D spending by patent data. Although evaluating technology stock is very difficult, the flow of R&D expenditure during the previous year is far from the perfect measure of the firm's technological capability. Consequently, this paper estimates the following:

$$FDI = \alpha + \beta_1 \ln\left(1 + \frac{PAT}{K}\right) + \beta_2 \ln Q + \beta_3 \ln \frac{K}{Q} + \beta_4 \ln HS + \gamma DUM + u \,. \quad (2)$$

The number of patents owned by the firm is denoted by *PAT*.[25] This specification allows us to relate FDI stock with the firm's technological capability also in stock terms.

Finally, this paper investigates whether or not the relation between R&D and FDI decisions is affected by the firm's experience with FDI in other regions.[26] Firms that have already invested in industrial countries may not need additional R&D spending at the decision of FDI in Asia because those firms must have already acquired high technological capability before investing in industrial countries. On the other hand, firms that have invested in Asia may need additionally active R&D when they decide to invest in industrial countries because the technological capability competing with rival firms in advanced countries is the final critical factor for those firms, which have satisfied other necessary requirements for overseas operations. Consequently, we expect that the coefficient on R&D intensity in the regression is insignificant or very small for FDI in Asia by firms that have invested in industrial countries, and relatively large for FDI in industrial countries by firms that have invested in Asia.

---

24 While the multinomial logit model is frequently used in FDI studies, our FDI count data is more information-rich. When continuous data, such as offshore production share (as in Fukao et al. (1994)) or joint venture share (as in Asiedu and Esfahani (2001), are available, Tobit model is preferable. Kogut and Chang (1991) use the negative binomial regression for Japanese FDI counts into U.S. industries.

25 Since the survey contains no other patent data, we cannot adjust differences in values or depreciations across patents. To control for the firm size consistently in stock term, *PAT* is divided by *K*, but our principal results are robust even if the patent-sales ratio is used instead.

26 This comparison is inspired by the analysis of the firm's choice among investing only in Asia, only in West, or both by Belderbos and Sleuwaegen (1996).

Our regressions have so far compared coefficients estimated from separate regressions of different measures of FDI. However, it remains to be known whether the destination of FDI (to industrial countries than Asia) or the ownership structure (majority than minority) relatively dictates the results. Therefore, to discriminate the destination effect from the ownership effect, this paper replaces the dependent variable of absolute level of FDI by the relative share as follows.

$$\frac{FDI\_Ind\_Maj}{FDI\_World\_Maj} = \alpha + \beta_1 \ln\left(1 + \frac{R\&D}{Q}\right) + \beta_2 \ln Q + \beta_3 \ln\frac{K}{Q} + \beta_4 \ln HS + \gamma DUM + u \tag{3}$$

This equation is estimated by Tobit because no share can be beyond zero and one. The positive β_1 in (3) indicates that the destination effect is stronger than the ownership effect. Similar regressions are also conducted for the share of industrial countries in all minority-owned FDI, the share of majority-owned FDI in all FDI to industrial countries, and the share of majority-owned FDI in all FDI to Asia. These regression results will distinguish whether destination or ownership of FDI is more strongly affected by R&D intensity.

IV. Estimation Results

Summary Statistics

This section reports empirical results from our sample. Before discussing regression results, descriptive statistics of variables used for estimation is informative. Table 2 clearly shows remarkable variations across firms. On average, each FDI firm has two or three foreign subsidiaries, while each R&D firm spends around three percent of their sales on R&D.[27]

The correlation between variables is summarized in Table 3. As expected, among the firms with strictly positive R&D and FDI, the correlation of FDI is high with sales (0.47 to

[27] The published aggregated statistics report similar average FDI and slightly higher R&D intensity.

0.52), also clearly positive with R&D intensity (0.24 to 0.35) and lower but also positive with human skills (0.14 to 0.23). However, if all firms with no R&D or no FDI are included, FDI becomes much less correlated with R&D and other variables. The correlation of FDI is now at most 0.2 with sales and far less than 0.1 with other variables. This contrast suggests the importance of including firms with no FDI or no R&D in investigating whether or not the estimates obtained only from FDI firms are biased.

OLS Results from the Restricted Sample

Table 4 reports the OLS results for the specification (1) from the sample restricting to firms with FDI and R&D both strictly positive. Although it is larger than those used in previous studies, the sample size is limited to around one thousand firms. The main findings from this benchmark case are as follows.

First, for majority-owned FDI, the effect of R&D on the extent of FDI in industrial countries is substantially larger than FDI in Asia. This finding is consistent with previous results, including Belderbos and Sleuwaegen (1996) and Fukao et al. (1994).

Second, the effect of R&D is found statistically significant on FDI in Asia at 1998, contrary to the previous results from 1980s data by Belderbos and Sleuwaegen (1996) and Fukao et al. (1994). Although Belderbos and Sleuwaegen (1996) cited the relative absence of local competing firms in the region in discussing their results, this paper confirms that relative R&D strengths in Japanese and Asian firms have drastically changed in the last decade. However, we must note that the gap in the magnitude of the R&D coefficient between Asia and industrial countries still remains remarkably large. We will discuss the comparison between FDI destinations again later.

Third, other variables are also precisely estimated. The firm size is significantly positively related with the extent of FDI both in industrial countries and Asia, suggesting fixed sunk entry costs for FDI. The physical capital intensity is found insignificant in this case. Firms with richer accumulation of human capital are more likely to directly invest significantly in industrial countries with majority ownership. Thus, as expected, intangible assets in technology and in human capital work similarly for FDI.

Finally, to the contrary, the significant contrast in the effects of R&D between industrial countries and Asia is not found in minority-owned FDI. Since R&D-driven FDI tends to seek majority ownership to internalize the gain from R&D, FDI with minority ownership is likely to be induced by factors omitted in our regressions, such as the proximity to markets, or low production costs in the host country.

Alternative Estimation Results

This section reports regression results with alternative methods or data, focusing on the comparison within majority-owned FDI. First, Table 5 reports results from larger samples including no-FDI firms as well as no-R&D firms. As a result, the sample size increases to 95,143 firms, reported in the columns (1) and (2). Besides, by dropping explanatory variables other than R&D and output, we cover exactly all the firms in our data set: 118,300 firms in the columns (3) and (4). In estimations, we consider that FDI cannot be negative.[28] Substantially larger effect of R&D on FDI in industrial countries than that in Asia is confirmed robust.

In addition to the confirmation of our main finding, the comparison of regression results reported in Tables 4 and 5 reveals the following interesting points. First of all, although it

[28] Since the survey has no information on exits from FDI or closure of foreign subsidiaries, all FDI figures are non-negative. Since maximum likelihood calculations for count data models did not converge within reasonable numbers of iterations, this paper employs Tobit model, which takes account of the corner solution constraint. Since our sample is now larger than 118 thousand, neglecting the integer constraint may not be serious. We will discuss regressions for count data later.

remains consistently larger than that on FDI in Asia, the impact of R&D on FDI in industrial countries is found to be less remarkable if no-FDI or no-R&D firms are included. The coefficient on R&D intensity is estimated to be as small as half of the OLS estimate from the restricted sample. This indicates that results dependent on restricted samples composed only of FDI firms may considerably overestimate the effect of R&D on FDI. Our estimates from the comprehensive sample indicate that a ten-percent rise in R&D expenditure relative to sales, evaluated at the mean, results in the opening of approximately merely one (1.498) new majority-owned foreign affiliate in an industrial country, as opposed to approximately three (3.056) affiliates as previously estimated from the restricted sample.[29] Such an overestimation may not be enormous, but should not be negligible in discussing the impacts of various policies in the real world. For example, R&D subsidy is supposed to enhance international competitiveness of individual firms, but its effect on overseas business operations of the country as a whole will be limited if large numbers of no-FDI firms are considered.

Other noteworthy findings from the comparison across different samples are as follows. First, the capital-output ratio, which was insignificant in OLS on the restricted sample, becomes precisely estimated in larger samples. Second, the impact of managerial skills on FDI in Asia gains statistical significance if no-FDI or no-R&D firms are included.[30] This second change is plausible because the comparison within FDI firms ignores that those firms tend to be noticeably richer in human capital than domestic firms.

This paper further checks the robustness of our results as follows. First, since our measure of FDI is the number of foreign subsidiaries, the results from regressions appropriate

---

[29] This calculation is based on the estimated coefficient reported in the column (1) in Tables 4 and 5 and the average shown in Table 2 for the R&D-sales ratio.

[30] Belderbos and Sleuwaegen (1996) find significantly positive effect of human capital intensity on FDI both in West and Southeast Asia in the 1980s.

for count data are shown in Table 6.[31] This table confirms that the impacts of R&D and of human skills on FDI in industrial countries remain substantially larger than FDI in Asia.[32] Consequently, the integer constraint does not affect our main findings.

Second, this paper uses patent data to check the robustness of our results based on R&D flow data. As reported in Table 7, we again find larger effect of technological capability on FDI in industrial countries than FDI in Asia, both from the restricted sample composed only of the firms with FDI and *PAT* both strictly positive and from the whole sample including no-FDI firms and no-patent firms. Furthermore, the inclusion of domestic and no-patent firms decreases the coefficient estimate on technological capability to around the half of that from the restricted sample. Therefore, the use of R&D expenditure data, as employed in most previous studies, does not affect our principal results.

Impact of FDI experience in other regions

Table 8 presents the regression results investigating the effect of the firm's FDI experience in other regions. Previous regressions have ignored whether or not the same firm simultaneously invested in other regions, but accumulated experiences in global business are likely to affect a firm's FDI decisions. The most notable finding in Table 8 is that R&D intensity is statistically insignificant in determining the extent of FDI in Asia for firms that own their affiliates in industrial countries.[33] This result is exactly as expected because the presence of

---

31 Since the assumption of equality between mean and variance is rejected, the negative binomial regression is used for the restricted sample. Since maximum likelihood calculation for negative binomial regressions did not converge within reasonable numbers of iterations, we use the Poisson model for the sample including no-FDI firms. Since maximum likelihood calculation for count data regressions did not converge in the larger samples including no-R&D firms, we use the Tobit model.

32 Possibly since many small-sized, non-innovative firms invest mostly in Asia, R&D loses its statistical significance in the regressions on FDI in Asia.

33 Since this sample consists of all firms with at least one affiliate in industrial countries, and, as a result, includes firms with no affiliates in Asia at all, these firms are different from the "global firms" investing in both regions, as defined by Belderbos and Sleuwaegen (1996).

these firms in industrial countries proves their already high technological capability. In contrast, firms that have their affiliates in Asia tend to require remarkably active R&D in order to make the move to FDI in industrial countries. Somewhat surprisingly, the magnitude of the effect of R&D on FDI in industrial countries by firms that have affiliates in Asia is substantially larger than even that by firms with no overseas affiliates in Asia at all. This finding, however, is plausible because, in deciding on FDI in an industrial country, their technological capability is likely to be the final critical determinant for firms that already have experienced with foreign affiliate operations, but may be just one of many important factors for firms that have no FDI experience. Combined with our previous findings, this additional evidence indicates that the positive association between R&D and FDI is not universal across all firms, but rather concentrated on the extent of FDI in industrial countries by firms that have invested in Asia. Although we should be cautious in interpreting a cross-section result, our use of comprehensive firm-level data reveals that the effect of R&D on FDI is heterogeneous depending on the firm's FDI experience.

Regression of FDI Shares

The results from the regressions of relative FDI shares are reported in Table 9. The share of FDI to industrial countries significantly increases with R&D intensity of the firm, while the share of majority-owned FDI has insignificant relationship. Thus, R&D tends to more strongly affect the destination rather than ownership preference of FDI. Since our survey, however, does not distinguish FDI with full ownership in majority-owned FDI, this finding of insignificant R&D effect on ownership may be partly affected by this mixed-up because the full ownership is supposed to be the distinctively superior way of internalizing the gains from R&D.[34]

[34] Barbosa and Louri (2002) find that R&D significantly increases FDI with full ownership, while

The same regression of FDI shares also shows that human skill intensity significantly raises the share of majority-owned FDI in total FDI to industrial countries. Since technology or gains from R&D, compared with human managerial skills, are supposed to be less difficult to transact in arm's length trade, then, our finding that R&D intensity is more related with FDI destination and that human skill intensity is more related with FDI ownership appears rather plausible. Since these regressions record very low R^2 due partly to a large number of censored data, however, additional investigations will be required before the final conclusion discriminating destination vs. ownership effects.

V. Concluding Remarks

This paper has investigated the relationship between technological capability and FDI, using firm-level data for 118,300 Japanese manufacturers. The relation between R&D and FDI is confirmed sizably stronger for FDI in industrial countries than FDI in Asia. However, the inclusion of no-FDI and/or no-R&D firms reduces the coefficient estimate on R&D intensity approximately by half in the case of majority-owned FDI in industrial countries. Therefore, the positive relationship between R&D and FDI is non-negligibly overestimated if those large numbers of innovative domestic firms are neglected.

In spite of these findings, important tasks remain for future independent work. For example, if the firm-level data of this survey is linked with other detailed FDI data, we will be able to control for the size of FDI and to further disaggregate regional destinations of FDI. These developments will certainly enrich our findings in the future.

---

the relation is insignificant for FDI with less-than-full majority ownership in Portugal. Based on industry-level data, Kogut and Chang (1991) report that the effect of R&D on FDI is significant for FDI into new plants, not for FDI in joint ventures by Japanese FDI into U.S.

Acknowledgement

The Ministry of Public Management allowed me to have access to original micro-data files in the government of Japan by No. 428 on July 22, 2002. Kazuyuki Motohashi and Junko Sakamoto of the Ministry of Economy, Trade and Industry were helpful in arranging this access. An earlier version of this paper was presented at the *International Conference on New Development in Asia Pacific Region: Economic Analysis using Micro Data*. Valuable comments from conference participants are acknowledged. The research for this paper is partly supported by the Grant-in-Aid for Scientific Research Nos. B14330012 and C13630056 from Ministry of Education and Science. All remaining errors are mine.

REFERENCES

Asiedu, Elizabeth, and Hadi Salehi Esfahani, 2001, Ownership Structure in Foreign Direct Investment Projects, *Review of Economics and Statistics* 83, pp. 647-662.

Barbosa, Natalia, and Helen Louri, 2002, On the Determinants of Multinationals' Ownership Preferences: Evidence from Greece and Portugal, *International Journal of Industrial Organization* 20, pp. 493—515.

Belderbos, Rene, and Leo Sleuwaegen, 1996, Japanese Firms and the Decision to Invest Abroad: Business Groups and Regional Core Networks, *Review of Economics and Statistics* 78, pp. 214—220.

Caves, Richard, 1996, *Multinational Enterprise and Economic Analysis*, second edition, Cambridge University Press, Cambridge.

Fukao, Kyoji, Toshiya Izawa, Morio Kuninori, and Toru Nakakita, 1994, R&D Investment and Overseas Production: An Empirical Analysis of Japan's Electric Machinery Industry Based on Corporate Data," *Bank of Japan Monetary and Economic Studies* 12, pp. 1—60.

Kogut, Bruce, and Sea Jin Chang, 1991, Technological Capability and Japanese Foreign Direct Investment in the United States, *Review of Economics and Statistics* 73, pp. 401—413.

Okabe, Misa, 2003, Relationship between Domestic Research and Development Activity and Technology Importation: An Empirical Investigation of Japanese Manufacturing Industries, *Asian Economic Journal* 17, pp. 265—280.

United Nations Center on Transnational Corporations (UNCTC), 1992, *The Determinants of Foreign Direct Investment: A Survey of the Evidence*, United Nations Publications, New York.

TABLE 1. — DESCRIPTIVE SUMMARY OF FDI AND R&D

(A) Number of Firms

	FDI>0	FDI=0	TOTAL
R&D>0	2,489	17,150	19,639
R&D=0	1,292	97,369	98,661
TOTAL	3,781	114,519	118,300

(B) FDI

(FDI>0)	R&D>0	R&D=0	R&D/No-R&D
World_Majority	4.09	1.52	2.68
Asia_Majority	2.53	1.31	1.94
World_Minority	2.42	1.52	1.59
Asia_Minority	2.13	1.48	1.43

(C) R&D intensity

(R&D>0)	FDI>0	FDI=0	TOTAL
(%)	2.60	2.73	2.71

(D) Sales

(Mil. ¥)	FDI>0	FDI=0	FDI/No-FDI
R&D>0	70,034	3,403	20.58
R&D=0	9,517	678	14.04
R&D/No-R&D	7.36	5.02	(Av. Sales=2,629)

Notes: The column or row R&D/No-R&D (FDI/No-FDI, respectively) calculates the ratio of corresponding value for firms with positive R&D (firms with positive FDI) over that for firms with no R&D (firms with no FDI).

TABLE 2. — SUMMARY STATISTICS OF VARIABLES

	NUMBER OF OBSERVATIONS	AVERAGE	STANDARD DEVIATION
FDI (World_Majority)	2,468	3.32	7.29
FDI (Asia_Majority)	1,862	2.14	3.19
FDI (World_Minority)	1,831	2.15	3.16
FDI (Asia_Minority)	1,528	1.93	2.60
R&D/Q (%)	19,314	2.71	15.35
Q	118,300	2,629	45,976
K/Q	96,515	0.43	3.46
HS	118,300	4.11	5.85

Notes: See text for definition of variables. FDI is counted by the number of foreign subsidiaries, while other variables are originally measured in million yen.

TABLE 3. — CORRELATION BETWEEN VARIABLES

Firms with FDI and R&D both strictly positive (464 observations)

	MajI	*MajA*	*MinI*	*MinA*	*R&D/Q*	*Q*	*K/Q*	*HS*
MajI	1.000							
MajA	0.686	1.000						
MinI	0.684	0.512	1.000					
MinA	0.428	0.629	0.560	1.000				
R&D/Q	0.349	0.336	0.249	0.239	1.000			
Q	0.505	0.518	0.466	0.476	0.358	1.000		
K/Q	0.012	–0.005	0.056	0.077	0.086	0.132	1.000	
HS	0.231	0.232	0.140	0.179	0.214	0.417	–0.011	1.000

Firms with no R&D or no FDI included (95,143 observations)

	MajI	*MajA*	*MinI*	*MinA*	*R&D/Q*	*Q*	*K/Q*	*HS*
MajI	1.000							
MajA	0.666	1.000						
MinI	0.569	0.463	1.000					
MinA	0.429	0.554	0.478	1.000				
R&D/Q	0.079	0.080	0.062	0.062	1.000			
Q	0.171	0.216	0.156	0.187	0.059	1.000		
K/Q	0.009	0.009	0.010	0.008	0.039	–0.072	1.000	
HS	0.055	0.063	0.044	0.053	0.049	0.215	–0.046	1.000

Notes: In FDI, *Maj* (*Min*) represents majority ownership (minority ownership, respectively), and *I* (*A*) denotes industrial countries (Asia, respectively) as destination of FDI. FDI in four categories is in number of foreign subsidiaries, while other variables are in logarithm. For *R&D/Q*, the logarithm is taken after adding one.

TABLE 4. — OLS RESULTS FROM THE RESTRICTED SAMPLE

	(1) Industrial_Maj	(2) Asia_Maj	(3) Industrial_Min	(4) Asia_Min
$\ln(1+R\&D/Q)$	43.343 (12.530)	9.763 (4.331)	8.559 (2.816)	12.678 (3.699)
$\ln Q$	1.486 (0.134)	0.943 (0.092)	0.235 (0.035)	0.505 (0.053)
$\ln K/Q$	0.185 (0.157)	0.107 (0.102)	0.031 (0.036)	0.066 (0.065)
$\ln HS$	0.472 (0.198)	0.122 (0.112)	0.077 (0.059)	0.106 (0.095)
R^2	0.273	0.276	0.186	0.232
Number of observations	1,266	1,266	1,056	1,056

Notes: This table covers only firms with R&D and FDI both strictly positive. Estimated heteroskedasticity-consistent standard errors are in parentheses. Industry dummies are included.

TABLE 5. — RESULTS FROM LARGER SAMPLES

	(1) Industrial	(2) Asia	(3) Industrial	(4) Asia
$\ln(1+R\&D/Q)$	21.246 (1.764)	9.179 (1.096)	23.665 (1.606)	10.245 (0.987)
$\ln Q$	3.974 (0.094)	1.956 (0.042)	4.257 (0.097)	2.025 (0.042)
$\ln K/Q$	1.397 (0.143)	0.516 (0.057)	-----	-----
$\ln HS$	1.791 (0.157)	0.513 (0.063)	-----	-----
Statistics	Log likelihood = –6181.382 Pseudo R^2 = 0.370 Left-censored obs. = 93,860	Log likelihood = –8989.287 Pseudo R^2 = 0.285 Left-censored obs. = 93,285	Log likelihood = –6306.346 Pseudo R^2 = 0.374 Left-censored obs. = 117,017	Log likelihood = –9134.983 Pseudo R^2 = 0.297 Left-censored obs. = 116,438
Number of observations	95,143	95,143	118,300	118,300

Notes: The dependent variable is FDI with majority ownership in all cases. The sample covers all firms. The equation is estimated by left-censored Tobit. Industry dummies are included.

TABLE 6. — REGRESSIONS FOR COUNT DATA

	(1) Industrial (FDI firms)	(2) Asia (FDI firms)	(3) Industrial (including no-FDI firms)	(4) Asia (including no-FDI firms)
$\ln(1 + R\&D/Q)$	7.395 (1.582)	0.731 (0.905)	3.505 (0.343)	−1.155 (1.149)
$\ln Q$	0.731 (0.027)	0.336 (0.016)	0.877 (0.025)	0.803 (0.021)
$\ln K/Q$	0.290 (0.070)	0.056 (0.038)	0.402 (0.059)	0.247 (0.046)
$\ln HS$	0.273 (0.073)	0.031 (0.038)	0.298 (0.077)	0.183 (0.048)
Statistics	Log likelihood = –1758.842 Pseudo R^2 = 0.249	Log likelihood = –2186.070 Pseudo R^2 = 0.160	Log likelihood = –5462.011 Pseudo R^2 = 0.646	Log likelihood = –5530.298 Pseudo R^2 = 0.537
Number of observations	1,266	1,266	19,101	19,101

Notes: The columns (1) and (2) are from negative binomial regression only for FDI firms, while the columns (3) and (4) are from Poisson regression including no-FDI firms. In all four cases, no-R&D firms are excluded. Industry dummies are included.

TABLE 7. — REGRESSIONS WITH PATENT DATA

	(1) Industrial (*FDI* and *PAT* both positive)	(2) Asia (*FDI* and *PAT* both positive)	(3) Industrial (All firms)	(4) Asia (All firms)
$\ln(1+PAT/K)$	13.563 (4.635)	6.600 (2.265)	7.904 (1.383)	3.347 (0.751)
$\ln Q$	1.973 (0.215)	1.144 (0.130)	4.052 (0.096)	1.987 (0.042)
$\ln K/Q$	0.712 (0.253)	0.298 (0.162)	1.585 (0.146)	0.565 (0.058)
$\ln HS$	0.762 (0.330)	0.169 (0.163)	1.892 (0.158)	0.541 (0.063)
Statistics	R^2=0. 266	R^2=0. 285	Log likelihood = – 6214.596 Pseudo R^2 = 0. 366 Left-censored obs. = 93,860	Log likelihood = – 9002.170 Pseudo R^2 = 0. 284 Left-censored obs. = 93,285
Number of observations	974	974	95,143	95,143

Notes: The columns (1) and (2) are from OLS regressions over the firms with *FDI* and *PAT* both strictly positive, while the columns (3) and (4) are left-censored Tobit results from all firms. Industry dummies are included.

TABLE 8. — IMPACT OF FDI IN THE OTHER REGION

	(1) *Ind. FDI* (Firms with Asia FDI)	(2) *Ind. FDI* (Firms with *No* Asia FDI)	(3) *Asia FDI* (Firms with Ind. FDI)	(4) *Asia FDI* (Firms with *No* Ind. FDI)
$\ln(1+R\&D/Q)$	56.229 (9.581)	10.212 (1.229)	5.945 (5.639)	3.551 (1.124)
$\ln Q$	3.732 (0.176)	1.997 (0.083)	2.226 (0.110)	1.040 (0.035)
$\ln K/Q$	0.953 (0.357)	0.821 (0.102)	0.094 (0.225)	0.294 (0.039)
$\ln HS$	1.647 (0.434)	0.874 (0.110)	0.121 (0.289)	0.209 (0.043)
Statistics	Log likelihood = –2602.048 Pseudo R^2 = 0.183 Left-censored obs. = 1,181	Log likelihood = –3271.671 Pseudo R^2 = 0.289 Left-censored obs. = 92,679	Log likelihood = –2283.674 Pseudo R^2 = 0.121 Left-censored obs. = 606	Log likelihood = –6311.211 Pseudo R^2 = 0.189 Left-censored obs. = 92,679
Number of observations	1,858	93,285	1,283	93,860

Notes: The dependent variable in the column (1) is majority-owned FDI in industrial countries by the firms that have invested in Asia, while (2) is from the firms that have *not* invested in Asia. The column (3) is from firms that have invested in industrial countries, while (4) is from firms that have *not* invested in industrial countries. The model is estimated by left-censored Tobit in all cases. Industry dummies are included.

TABLE 9. — REGRESSION OF FDI SHARE

	(1) $\frac{Ind\_Maj}{World\_Maj}$	(2) $\frac{Ind\_Min}{World\_Min}$	(3) $\frac{Ind\_Maj}{Ind\_All}$	(4) $\frac{Asia\_Maj}{Asia\_All}$
$\ln(1+R\&D/Q)$	5.482 (1.111)	7.570 (2.633)	1.377 (1.865)	–0.887 (2.000)
$\ln Q$	0.174 (0.018)	0.185 (0.036)	0.058 (0.030)	0.0892 (0.026)
$\ln K/Q$	0.180 (0.038)	0.177 (0.082)	0.114 (0.070)	0.137 (0.055)
$\ln HS$	0.228 (0.046)	0.046 (0.089)	0.235 (0.084)	–0.005 (0.061)
Statistics	Log likelihood = –2332.737 Pseudo R^2 = 0.099 Left-censored obs. =1,181 Right-censored obs.= 606	Log likelihood = –1419.626 Pseudo R^2 = 0.050 Left-censored obs. =1,271 Right-censored obs.=300	Log likelihood = –1351.271 Pseudo R^2 = 0.021 Left-censored obs. = 271 Right-censored obs.= 999	Log likelihood = –2903.453 Pseudo R^2 = 0.016 Left-censored obs. = 979 Right-censored obs.= 1,311
Number of observations	2,464	1,826	1,554	2,837

Notes: In the denominator, *All* represents all FDI to each region (both majority-owned and minority-owned FDI combined). The equation is estimated by Tobit with both sides censored. Industry dummies are included.