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Overseas R&D Activities and Home Productivity Growth: Evidence from Japanese Firm-Level Data*

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Abstract

This paper investigates the impact of overseas subsidiaries' R&D activities on the productivity growth of parent firms using firm-level panel data for Japanese multinational enterprises. We distinguish between overseas R&D for the utilization and acquisition of foreign advanced knowledge, or innovative R&D, and overseas R&D for the adaptation of technologies and products to local conditions, or adaptive R&D. Our major finding is that overseas innovative R&D helps to raise the productivity growth of the parent firm, while overseas adaptive R&D has no such effect. In addition, we examine whether overseas innovative R&D has an indirect effect on home productivity growth by improving the rate of return on home R&D. However, we find no evidence of such an indirect effect, suggesting that overseas innovative R&D does not engender any knowledge transfers from overseas to home R&D units.

Keywords: overseas R&D activities, innovative R&D, adaptive R&D, multinational enterprises, total factor productivity.

JEL classifications: F23, L20, O30.

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1 Introduction

Overseas R&D activities by multinational enterprises (MNEs) have expanded significantly in recent years (Kuemmerle, 1999; Granstrand, 1999; Patel and Vega, 1999; Pearce, 1999; Pearce and Papanastassiou, 1999; Le Bas and Sierra, 2002). The literature also indicates that one of the major motives of such overseas R&D activities is the utilization and acquisition of foreign advanced knowledge that would otherwise be unavailable in the home country. Therefore, one would expect that the R&D activities of overseas subsidiaries benefit their parent firms.

However, empirical evidence on such benefits from overseas R&D has been mixed. To our knowledge, the first to examine the impact of overseas R&D on parent firms' productivity growth was Fors (1997). Using Swedish firm level data, he found no significant impact. Similarly, Iwasa and Odagiri (2004) found that Japanese firms' research-oriented R&D in the United States had no impact on the extent of innovation in Japan. These results may not be surprising, given previous findings that knowledge spillovers are geographically localized and that international knowledge diffusion is costly (Jaffe, Trajtenberg, and Henderson, 1993; Branstetter, 2001). On the other hand, Branstetter (2006), for example, found that Japanese firms' citations of U.S. patents are positively correlated with the number of R&D units they had in the United States, suggesting that overseas R&D facilitates the diffusion of foreign knowledge to the home country.

This study aims to provide new evidence on whether parent firms benefit from overseas R&D and, if so, how, using a firm-level panel dataset for Japanese parent firms in manufacturing industries and their overseas subsidiaries for the period 1996–2002. This paper contributes to the existing literature in the following two aspects. First, we classify overseas R&D activities into two types. Presumably, one of the main goals of R&D activities in foreign subsidiaries is to utilize and acquire foreign advanced knowledge that is unavailable in the home country. At the same time, however, firms also engage in overseas R&D activities to adapt existing technologies and products to the local conditions of the host country.[1] We will hereafter denote overseas R&D for the utilization and acquisition of foreign knowledge as innovative R&D and overseas R&D for the adaptation of technologies and products as adaptive R&D.[2] The fact that there are these two types of overseas R&D provide a possible explanation why Fors (1997), who did not make such a distinction, did not find a significant effect of overseas R&D on home productivity. In the present study, we use a rich firm-level dataset for Japanese MNEs that allows us to classify each overseas

[1] Examining U.S. MNEs, Teece (1977) finds that the costs of such adaptations account for 19 percent of total investment costs.

[2] Existing studies typically denote the former type as demand-led, home-base-exploiting, or research-oriented R&D, and the latter as supply-led, home-base-augmenting, or local-support-oriented R&D.

subsidiary's R&D activities as innovative or adaptive and to examine the effect of each type of R&D on parent firms' productivity growth.

Second, in addition to the direct effect of overseas R&D on the productivity of parent firms' *production activities*, measured by total factor productivity (TFP), we examine whether overseas innovative R&D improves the productivity of parent firms' *R&D activities*, measured by the rate of return on home R&D, and hence indirectly raises the productivity of *production* in the home country. A direct positive effect of overseas innovative R&D on home productivity would be interpreted as showing that parent firms' productivity in production benefits from overseas innovative R&D by utilizing the fruits of such R&D, such as new materials and computer chips, in home production activities. In contrast, a positive indirect effect would suggest that new knowledge created by overseas innovative R&D is transferred to the R&D units of parent firms, raising the rate of return on home R&D. We examine the indirect effect by incorporating an interaction term between home and overseas innovative R&D in the TFP growth regression.

Although several existing studies have noted the differences between the two types of overseas R&D, most remained silent on how each type of overseas R&D affects parent firms. An exception is the study by Iwasa and Odagiri (2004), which investigated the impact of innovative (research-oriented in their terminology) and adaptive (support-oriented) R&D performed by Japanese MNEs in the United States on the extent of innovation in Japan as measured by the number of patent applications. This paper differs from Iwasa and Odagiri (2004) in that while they focus on the impact of overseas R&D on home R&D, this study examines its impact on the productivity of both the production and R&D activities of parent firms in a unified estimation framework.[3]

Our results show that, overall, parent firms' TFP growth is not correlated with the total size of overseas R&D measured by the ratio of the total R&D expenditure of overseas subsidiaries to their parent firms' value added. This is consistent with the result of Fors (1997). However, once we disaggregate overseas R&D into the two types, we find that the direct effect of overseas innovative R&D on home TFP growth is positive, statistically significant, and large in size, while overseas adaptive R&D has no such effect. These results based on the distinction between the two types of R&D activities suggest that the puzzling result obtained by Fors (1997) may be due to the fact that his analysis mixes the two types of

[3]There are several other notable differences between the two studies. The first is sample size: Iwasa and Odagiri's (2004) sample is based on cross-section data for Japanese MNEs in the United States and is relatively small with only 137 observations, while our sample consists of panel data for Japanese MNEs in 27 countries with a total of 2,617 observations. Moreover, Iwasa and Odagiri (2004) do not correct for possible biases due to firm-specific fixed effects or the endogeneity of regressors, while we correct for those biases. The puzzling finding of Iwasa and Odagiri (2004) that adaptive R&D in the United States has a positive and significant effect on the extent of innovation in Japan while innovative R&D has no significant effect may be due to these shortcomings of their study.

overseas R&D. In addition, we find no evidence of any indirect effect of overseas innovative R&D: i.e., overseas innovative R&D does not boost the effect of home R&D on home TFP growth. This finding suggests that parent firms and their overseas subsidiaries are likely to perform R&D independently of each other, without much interaction between them. These results indicate that it is necessary to distinguish both between overseas innovative and adaptive R&D activities and between the direct and the indirect effect of overseas R&D in order to clarify how the rapidly growing R&D activities of foreign subsidiaries affect parent firms.

The remainder of the paper is organized as follows. Section 2 presents the estimation strategies employed in this study. Section 3 provides an explanation of the data and the variables used, while Section 4 reports our estimation results and relates them to preceding studies. Section 5 concludes.

2 Estimation Strategies

2.1 Estimation equation

To examine the effect of R&D activities of overseas subsidiaries on parent firms' productivity, we extend the framework of Griliches (1979, 1980) and assume a Cobb-Douglas production function for parent firms that incorporates home and overseas R&D stocks:

$$Y_{it} = A_{it} K_{it}^{\beta_K} L_{it}^{\beta_L} \left(S_{it}^{H}\right)^{\gamma_H} \left(S_{it}^{O}\right)^{\gamma_O}, \tag{1}$$

where Y_{it} stands for the value added of parent firm i in the home country at time t, A_{it} for a firm-specific parameter, K_{it} for the physical capital stock, and L_{it} for employment. S_{it}^{H} represents firm i's R&D stock at time t accumulated through R&D activities in the parent firm, whereas S_{it}^{O} is the R&D stock accumulated through R&D activities by firm i's overseas subsidiaries (superscript H stands for home, and O for overseas). For ease of presentation, we do not distinguish between overseas innovative and adaptive R&D in equation (1), although we will do so later when we present the estimation equation.

Taking the log of equation (1), we obtain

$$y_{it} = a_{it} + \beta_K k_{it} + \beta_L l_{it} + \gamma_H s_{it}^{H} + \gamma_O s_{it}^{O}, \tag{2}$$

where $x_{it} \equiv \ln X_{it}$ for any variable X. We further first-difference this and obtain

$$\Delta y_{it} = \Delta a_{it} + \beta_K \Delta k_{it} + \beta_L \Delta l_{it} + \gamma_H \Delta s_{it}^{H} + \gamma_O \Delta s_{it}^{O}, \tag{3}$$

where $\Delta x_{it} = x_{it} - x_{i,t-1}$ for any variable x. Assuming that S_{it}^{H}/Y_{it} and S_{it}^{O}/Y_{it} are constant for any i and t and that R&D stocks do not depreciate, we can rewrite equation (3) as

$$\Delta y_{it} = \Delta a_{it} + \beta_K \Delta k_{it} + \beta_L \Delta l_{it} + \sigma_H \frac{R\&D_{i,t-1}^{H}}{Y_{i,t-1}} + \sigma_O \frac{R\&D_{i,t-1}^{O}}{Y_{i,t-1}}, \tag{4}$$

where $R\&D^H_{it}$ is the amount of R&D expenditure of parent firm i at time t, $R\&D^O_{it}$ is the amount of total R&D expenditure of firm i's overseas subsidiaries, and $\sigma_H = \gamma_H Y/S^H$ and $\sigma_O = \gamma_O Y/S^O$. Note that σ_H and σ_O can be interpreted as the rate of return on home and overseas R&D, respectively.

Previous studies have employed either equation (2) or (4) to estimate the effects of R&D activities on firm-level productivity. With regard to estimation, each of the two equations has its own drawbacks, and in the case of our dataset for Japanese MNEs, estimation of equation (2) seems to be more problematic. When estimating a level equation such as (2), we need the values of firm-level R&D stocks, which are usually computed from estimated initial R&D stocks and subsequent R&D expenditures using the perpetual inventory method. However, since firm-level panel data usually do not cover a long period, estimation of initial R&D stocks is not easy and often requires strong assumptions. For example, Basant and Fikkert (1996) and Ornaghi (2006) construct firm-level initial R&D stocks assuming that the industry trend in R&D expenditures during the pre-sample period can be applied to any individual firm. However, since overseas R&D activities are a relatively recent phenomenon, reliable aggregate data on the R&D expenditures of overseas subsidiaries of Japanese firms are not available for the period before 1996, the initial year of our dataset.

Accordingly, we presume that biases in the estimation of the level equation (2) using the estimated amount of R&D stocks are larger than biases in the estimation of the growth equation (4) using R&D expenditures. Therefore, we employ equation (4) rather than equation (2) as our estimation equation, although we realize that the derivation of equation (4) requires several assumptions.

2.2 Estimation method

A major econometric issue in estimating equation (4) is the possible endogeneity of inputs. Another issue is that if the logs of capital and labor have near unit root properties and hence their first differences, Δk and Δl, are close to white noise, estimates of the capital and labor elasticity may be biased. To alleviate possible biases due to the endogeneity and autocorrelation of inputs, we employ a two-step procedure in which we first construct the growth rate of parent firms' TFP and then estimate the effects of home and overseas R&D on TFP growth. Similar two-step procedures have been employed in many previous studies that examine the effects on firm-level productivity, including recent papers by Javorcik (2004) and Aghion, Blundell, Griffith, Howitt, and Prantl (2004).

More specifically, we follow Caves, Christensen, and Diewert (1982) and Good, Nadiri, and Sickles (1996) and employ a chained multilateral index of the firm-level TFP given by

$$\begin{aligned}\ln TFP_{it} = & \left(\ln Y_{it} - \overline{\ln Y_t}\right) + \sum_{\tau=1}^{t}\left(\overline{\ln Y_\tau} - \overline{\ln Y_{\tau-1}}\right) \\ & - \frac{1}{2}\sum_{j=1}^{J}(s_{ijt} + \overline{s_{jt}})\left(\ln X_{ijt} - \overline{\ln X_{jt}}\right) \\ & - \sum_{\tau=1}^{t}\frac{1}{2}\sum_{j=1}^{J}(\overline{s_{j\tau}} + \overline{s_{j,\tau-1}})\left(\overline{\ln X_{j\tau}} - \overline{\ln X_{j,\tau-1}}\right),\end{aligned} \tag{5}$$

where X_{ijt} is the amount of input factor $j \in \{K, L\}$ of firm i at time t, and s_{ijt} is the cost share of factor j. $\overline{\ln Y_t}$, $\overline{\ln X_{jt}}$, and $\overline{s_{jt}}$ are the arithmetic means of $\ln Y_{it}$, $\ln X_{ijt}$, and s_{ijt}, respectively, across all i in the same 2-digit industry at time t. Equation (5) implies that the multilateral TFP index, TFP_{it}, measures firm i's TFP level at time t relative to a hypothetical firm at time 0 whose input shares are equal to the arithmetic mean of input shares, and whose output and input quantities are equal to the geometric mean of output and input quantities.

Rewriting equation (3) with the use of the TFP index and incorporating possible differences between the effects on TFP growth of innovative and adaptive R&D by overseas subsidiaries, our benchmark estimation equation is given by

$$\begin{aligned}\Delta \ln TFP_{it} = & \sigma_H \left(\frac{R\&D^H_{i,t-1}}{Y_{i,t-1}}\right) + \sigma_{OI}\left(\frac{R\&D^{OI}_{i,t-1}}{Y_{i,t-1}}\right) + \sigma_{OA}\left(\frac{R\&D^{OA}_{i,t-1}}{Y_{i,t-1}}\right) \\ & + \lambda_i + \mu_t + \varepsilon_{it},\end{aligned} \tag{6}$$

where $R\&D^{OI}_{it}$ and $R\&D^{OA}_{it}$ are the total amount of innovative and adaptive R&D expenditure of firm i's overseas subsidiaries, respectively, whereas λ_i denotes firm-specific fixed-effects, μ_t stands for time-specific effects, and ε_{it} is the error term.

In estimating equation (6), we apply the system generalized method of moments (GMM) estimation developed by Blundell and Bond (1998) to eliminate any possible endogeneity of the R&D intensity variables.[4] In the system GMM estimation, we apply GMM estimation to the system of equation (6) and its first-difference in which the firm-specific constant terms are eliminated, using the lagged first-differenced regressors as instruments for the original equation and the lagged regressors as instruments for the first-differenced equation. The lagged regressors should not be correlated with the contemporaneous error term, since they are predetermined. The major advantage of the system GMM, compared with its predecessor, the differenced GMM developed by Arellano and Bond (1991), is that in the latter, instruments are weak if regressors have near unit root properties, whereas this problem can be alleviated in the former. We apply two-step estimations of the system GMM

[4] System GMM estimation has been used in many previous empirical studies on productivity, such as Griffith, Harrison, and Van Reenen (2006) and Van Biesebroeck (2005).

to obtain larger efficiency. In addition, we use Windmeijer's (2005) methodology to obtain robust standard errors. The estimator thus obtained is consistent even in the presence of heteroskedasticity and autocorrelation and corrects for finite sample biases found in the two-step estimations.

2.3 The indirect effect of overseas R&D on TFP growth

In addition to the direct effect of overseas R&D represented by σ_{OI} and σ_{OA} in equation (6), we examine whether overseas innovative R&D indirectly affects home TFP growth by improving the productivity of home R&D measured by the rate of return on home R&D. For this purpose, we extend the estimation equation (6) and incorporate an interaction term between the home R&D intensity, $R\&D^H/Y$, and the overseas innovative R&D intensity, $R\&D^{OI}/Y$. In this extended estimation, we implicitly assume that the home-R&D elasticity of value added in the production function (1), γ_H, linearly depends on the overseas innovative R&D intensity, $R\&D^{OI}/Y$, so that σ_H in equations (4) and (6) also linearly depends on $R\&D^{OI}/Y$.

The difference between the direct and the indirect effect of overseas innovative R&D on home TFP growth is highlighted in the following example. Suppose that a Japanese MNE performs overseas innovative R&D in the United States and that the R&D unit in the United States successfully innovates new materials, microchips, or computer software. If the fruits of such innovation are used in the production activities of the parent firm in Japan, the quality of the final products of the parent firm rises, and hence its TFP level improves, just as the fruits of home R&D improve home TFP. This represents the direct effect of overseas innovative R&D on home TFP. But in addition, the productivity of home R&D measured by the rate of return on home R&D should also improve if the knowledge and know-how created and used in the innovative R&D activities in the United States are transferred to the parent firm's R&D units. This represents the indirect effect of overseas innovative R&D. In other words, the indirect effect, which can be captured by the interaction term between home and overseas R&D, refers to any potential knowledge transfers from overseas to home R&D units.

It should be noted that the absence of any indirect effect of overseas R&D as defined in this paper, i.e., a rate of return on home R&D that is independent of the size of overseas R&D, does not necessarily mean the absence of any interaction between home and overseas R&D. In particular, under a Cobb-Douglas production function such as equation (1), home and overseas R&D interact with each other in the sense that an increase in the stock of overseas R&D raises the marginal product of home R&D stock, even when no indirect effect of overseas R&D is present. In other words, the indirect effect of overseas R&D defined in this paper is referred to as a particular type of interaction between home and overseas R&D.

3 Data

3.1 Description of the dataset

For the estimation in this paper, we combine two firm-level datasets for the period 1996–2002, one for Japanese firms, the *Kigyo Katsudo Kihon Chosa* (Basic Survey of Enterprise Activities) and the other for overseas subsidiaries of Japanese MNEs, the *Kaigai Jigyo Katsudo Kihon Chosa* (Basic Survey of Overseas Business Activities). Both datasets are collected annually by the Ministry of Economy, Trade and Industry. Note that although responding to the first survey is compulsory, this is not the case for the survey on overseas subsidiaries. As a result, the response rate for the latter survey is about 60 percent.[5] The earliest year for which data for overseas R&D are available and the distinction between overseas innovative and adaptive R&D in a consistent manner is possible is 1996. Our sample consists of Japanese firms in manufacturing industries that have at least one overseas subsidiary. Details of the datasets and variables used are presented in Appendix A.

3.2 Classification of the two types of overseas R&D

Since the surveys include questions on the role of overseas R&D activities, we can classify the R&D activities of each subsidiary as innovative or adaptive according to firms' survey response.[6] The *Kaigai Jigyo Katsudo Kihon Chosa* (Basic Survey of Overseas Business Activities) included questions on the extent of each of six types of overseas R&D activity, i.e., basic research, applied research, development for the world market, development for the domestic market, design for the world market, and design for the domestic market. For each of these categories, overseas subsidiaries are provided with a choice of four answers: (1) expanding, (2) stable, (3) shrinking, and (4) absent. If subsidiaries' choice on the extent of a certain type of R&D activity was (1), (2), or (3), we regard them as being engaged in that type of R&D activity.[7] Using this information on the extent of the six types of R&D activity, we classify the R&D activities of each subsidiary: those engaged in basic research, applied research, or development for the world market (12.0 percent of all overseas subsidiaries)

[5]While our sample consists only of firms that responded to both surveys, the means of value added, the TFP level, and the R&D-value added ratio in our sample are not significantly different from the means for firms that only responded to the *Kigyo Katsudo Kihon Chosa*.

[6]Although data for overseas R&D are also available for 1995, the survey question asking about the role of overseas R&D was slightly different from that in other years. Probably for this reason, there was a wide discrepancy between the share of innovative R&D in total overseas R&D expenditures in 1995 and in other years. Therefore, we do not use the data for 1995.

[7]Among subsidiaries that chose (1), (2), or (3), roughly 30-40 percent chose (1), 60-70 percent chose (2), and only 2-3 percent chose (3), although these percentages vary to some extent across the different types of R&D activity.

are defined as subsidiaries performing innovative R&D, while subsidiaries not performing these activities but instead engaged in development for the domestic market or design (9.3 percent) are defined as subsidiaries performing adaptive R&D.[8]

Several remarks on this classification method in our baseline estimations should be noted. First, we classify development for the world market as innovative R&D, since according to our definition, the aim of overseas innovative R&D is to utilize and acquire foreign knowledge, whereas the aim of adaptive R&D is to adapt existing technologies and products to the local conditions of the host country. Second, 5.7 percent of all overseas subsidiaries reported positive R&D expenditures but did not specify the type of their R&D. We do not classify the R&D activities of these subsidiaries as either innovative or adaptive R&D. Third, we classify innovative and adaptive R&D ignoring the characteristics of host countries. Although most subsidiaries performing innovative R&D are located in developed countries, some are located in emerging markets such as South Korea, Taiwan, and China. Finally, these classification procedures mean that both subsidiaries that engaged in innovative R&D but not in adaptive R&D and subsidiaries that engaged in both types of R&D are classified as innovative R&D-performing subsidiaries. We do not distinguish between these two types of subsidiaries, since the former type constitutes only 0.3 percent of all subsidiaries in our dataset. Therefore, the effect of innovative overseas R&D may in fact reflect the effect of the combination of innovative and adaptive R&D. However, we cannot distinguish between the two effects due to data limitations. Recognizing these data issues, we experimented with several alternative classification methods, such as defining development for the world market as adaptive R&D, considering overseas subsidiaries that do not report the type of their R&D as performing adaptive R&D, and defining overseas R&D in any country other than the United States (the "technology frontier country") as adaptive R&D, regardless of the type of R&D. However, the results based on these alternative classifications were not substantially different from the benchmark results.

3.3 Summary statistics

Following a cleaning process, which is describe in Appendix A, our unbalanced panel on Japanese MNEs in all manufacturing industries contains data on 597 firms covering the period 1996-2002 for a total of 2,671 firm-year observations.[9] Among the 2,671 observations, the reported R&D expenditure by the parent firm and by overseas subsidiaries is positive in 2,443 and 1,340 cases, respectively. Also, there are 912 observations with positive expen-

[8]The *Kigyo Katsudo Kihon Chosa*, the survey on firms in Japan, does not include questions on the type of R&D performed by each firm. Therefore, we cannot distinguish between home innovative and adaptive R&D.

[9]Note that since we use the first lag of R&D variables, these observations include information on home and overseas R&D during the period 1996-2001.

diture on overseas innovative R&D and 480 with positive expenditure on overseas adaptive R&D.

Table 1 presents the aggregate R&D intensity, or the percentage ratio of the aggregate R&D expenditure to the aggregate value added of parent firms, by industry, by year, and in total. The ratio of parent firms' aggregate R&D expenditure to their own aggregate value added is 18.46 percent, while the ratio of overseas subsidiaries' R&D expenditure to parent firms' value added is 1.30 percent (last row). The aggregate intensity of overseas innovative and adaptive R&D is 0.61 and 0.44 percent, respectively. These figures suggest that the size of overseas R&D is substantially smaller than the size of home R&D and that innovative R&D makes up the greater part of overseas R&D.

The upper part of Table 1 shows that there is a wide discrepancy in the overseas R&D intensity across industries, ranging from less than 0.1 percent in the beverages, wood, publishing and printing, and coke and petroleum products industries, to more than 1 percent in the chemicals, rubber, electrical machinery and electronics, transportation equipment, precision instruments, and other manufacturing industries. To make this difference across industries even clearer, we classify them into two groups: five high-technology industries, which include chemicals, machinery and equipment, electrical machinery and electronics, transportation equipment, and precision instruments,[10] and all other industries which we denote as low-technology industries. Table 1 shows that the aggregate intensity of both home and overseas R&D in the five high-technology industries is substantially higher than the R&D intensity in the low-technology industries. In other words, the overseas R&D activities of Japanese MNEs are concentrated in high-technology industries in which the size of parent firms' R&D is also large.

Also shown in Table 1 are the trends over time in home and overseas R&D, indicating that the home R&D intensity has been relatively stable over time, while the overseas R&D intensity has been on an upward trend. In particular the aggregate ratio of overseas adaptive R&D expenditure to parent firms' value added has seen a marked rise, increasing from 0.32 percent in 1996 to 0.59 percent in 2001.

Summary statistics of TFP growth and the R&D intensity variables used in the regression are presented in Table 2. In addition to the summary statistics for the whole sample shown in the left columns, the table shows the mean and the standard deviation for high- and low- technology industries in the columns on the right.[11] The standard deviation of the overseas R&D intensity is substantial compared with its relatively small mean, indicating

[10]These industries are classified as high- or medium-high-technology industries in OECD (2003).

[11]The mean of the ratio of home (overseas) R&D expenditure to home value added shown in Table 2 is different from the aggregate home (overseas) R&D intensity presented in Table 1, since the former is the mean of figures for all observations whereas the latter is the ratio of the total (overseas) R&D expenditure of all observations to their total value added.

a large variation in the size of overseas R&D among Japanese MNEs. This large variation is observed even in high-technology industries.[12]

4 Estimation Results

4.1 Baseline results using observations on MNEs in all manufacturing industries

To begin the examination of the effect of overseas R&D on home TFP growth, we estimate equation (6) based on our sample of Japanese MNEs in all manufacturing industries and using ordinary least squares (OLS) and system GMM estimation. The results are shown in Table 3.[13]

Before discussing the main results, we should note that results from the system GMM estimation are preferred to the OLS results based on the following three tests. First, we test whether instruments used in the regression are orthogonal to the error term by the Hansen J statistic (the minimized value of the two-step GMM criterion function) and report its p value in the second last row of Table 3. Second, we test whether instruments are correlated with the regressors by performing OLS and checking the F statistic from the OLS, although for brevity we do not present the results. Finally, we test for the presence of second-order serial correlation in the first-differenced error term or the presence of first-order serial correlation in the error term of equation (6) using Arellano and Bond's (1991) statistic and report its p value in the last row of Table 3. In all GMM estimations in this paper, we find orthogonality between the error term and instruments, significant correlation between regressors and instruments, and the absence of second-order serial correlation. Therefore, we will rely on the GMM results when the results from the OLS and the GMM estimation are different.

We start with a simple specification in which we do not distinguish between innovative and adaptive R&D. According to the results reported in columns 1 and 2 of Table 3, the coefficient on the home R&D intensity, the ratio of the parent firm's R&D expenditure to its value added, is positive and statistically significant. The point estimate from the GMM estimation, 0.873, is substantially larger than the point estimate from the OLS estimation, 0.276, which is similar to the OLS results of Odagiri and Iwata (1986) and Goto and Suzuki (1989). The difference between the OLS and GMM results suggests that the error term in

[12] See Shimizutani and Todo (2005) for a more detailed description of overseas R&D by Japanese MNEs, including its geographic distribution by type of overseas R&D.

[13] In an earlier study Todo and Shimizutani (2005), we also examined the impact of overseas R&D on home productivity growth. Here, we extend our analysis by lengthening the data period by one year, by improving the methodology for the generation of the TFP level, by adding various alternative specifications to check the robustness of our results (see Section 4.2), and by examining differences between high-tech and low-tech industries (see Section 4.3).

equation (6) is negatively correlated with the home R&D intensity. This in turn implies contemporaneous positive correlation between productivity shocks and home R&D intensity, since equation (6) is based on the first difference of equation (2).

In contrast, the effect of the overseas R&D intensity, the ratio of overseas subsidiaries' R&D expenditure to the parent firm's value added, is insignificant at the 5-percent level both in the OLS and the GMM estimation. The result that the R&D activities of overseas subsidiaries have no significant effect on the productivity growth of the parent firm is consistent with Fors' (1997) study, which arrived at a similar result using Swedish firm-level data and different estimation methods.

We further distinguish between innovative and adaptive overseas R&D and perform the OLS and the system GMM estimation. The GMM results shown in column 4 of Table 3 indicate that the effect of the overseas innovative R&D intensity is positive and significant at the 1-percent level. The size of the estimated coefficient on overseas innovative R&D is substantial, suggesting that an increase in the ratio of expenditure on overseas innovative R&D to the parent firm's value added by one percentage point leads to a 4.9-percent increase in the TFP level of parent firms. In contrast, the effect of overseas adaptive R&D is insignificant both in the OLS and the GMM estimation. This difference between overseas innovative and adaptive R&D confirms our presumption that overseas innovative R&D, which aims at the utilization of foreign advanced knowledge, benefits home productivity, whereas overseas adaptive R&D, which aims at the adaptation of existing technologies and products to the local conditions of the host country, has no such effect.

We note that the result that the coefficient on the overseas innovative R&D intensity is substantially larger than the coefficient on the home R&D intensity should be interpreted with caution. Since the coefficient on the intensity of a particular type of R&D is equal to the elasticity of output with respect to the stock of that type of R&D multiplied by the ratio of the parent firm's output to that R&D stock (Section 2.1), our results do not necessarily suggest that the elasticity of output with respect to the stock of overseas innovative R&D (γ_O in equation [1]) is larger than the corresponding elasticity for home R&D (γ_H).[14]

Next, to test for the presence of any indirect effect of overseas innovative R&D on home TFP growth in terms of increases in the productivity of home R&D, measured by the rate of return on home R&D, we incorporate the interaction term between home and overseas innovative R&D into the estimation. The OLS and GMM results in columns 5 and 6 of

[14]To see this more clearly, assume that the ratio of home R&D to overseas innovative R&D in terms of stocks is equal to the corresponding ratio in terms of expenditures, 22.5 on average according to the figures in Table 2. Then, our finding that the coefficient on the home R&D intensity is 5.4 times as large as that on the overseas innovative R&D intensity implies that the elasticity of output with respect to the home R&D stock is indeed larger than that with respect to the overseas innovative R&D stock.

Table 3 indicate that the effect of the interaction term is insignificant.[15]

Using the example presented in Section 2.3, we interpret these results as showing that the *production activities* of the parent firm in Japan benefit from the outcome of overseas innovative R&D activities, such as new materials, microchips, and computer software, but the *R&D activities* of the parent do not benefit from the knowledge created by overseas innovative R&D. In other words, overseas innovative R&D does not promote the transfer of foreign knowledge to home R&D units, probably because the overseas subsidiaries of Japanese MNEs are performing innovative R&D independently, without close interaction with parent firms' R&D units.

Our finding that the effect of overseas innovative R&D on the rate of return on home R&D is absent conforms with the study by Iwasa and Odagiri (2004) which finds that the size of overseas innovative R&D in the United States has no impact on the level of innovation of the Japanese parent firm measured by the number of patent applications in Japan. In addition, our conclusion on the weak interaction between home and overseas R&D is also supported by survey responses from Japanese MNEs (Kiba, 1996) and interviews with managers of Japanese MNEs in the United States (Tanaka, Negishi, and Sakakibara, 2000)[16] as well as Criscuolo and Narula's (2005) finding that there are large obstacles to the promotion of effective knowledge transfer within European MNEs in the pharmaceutical industry.

Another related study is that by Branstetter (2006), who uses patent citation data for Japanese MNEs in the United States and finds that Japanese MNEs cite more US patents when they have a larger number of R&D units in the United States. Since Branstetter's finding suggests that overseas R&D promotes knowledge transfer to Japan, the findings of our study seem to be inconsistent with Branstetter (2006). However, one notable difference between Branstetter (2006) and our study is that Branstetter (2006) examines the impact of overseas R&D on the number of patent citations, a measure of *input* in R&D activities, while this study examines its impact on TFP growth, a measure of *output* of R&D. It may be this difference in methodologies that explains the different results.

[15] The effect of overseas innovative R&D, which was positive and significant in column 4, becomes insignificant. We presume that this is due to multicollinearity between the R&D intensity variables and their interaction term. This presumption is supported by the fact that the size of the coefficient on overseas innovative R&D in column 4 is similar to that in column 6.

[16] Kiba (1996) asked 19 Japanese MNEs about the interaction between home and overseas R&D and whether this was (a) large, (b) small, (c) beginning to emerge, or (d) nonexistent. The number of replies for each of these answers was zero, five, nine, and five, respectively. Tanaka, Negishi, and Sakakibara (2000) cite the manager of the R&D center of a Japanese electronics firm in the United States as saying that it is difficult for the R&D center to conduct joint research with the R&D unit of the parent firm in Japan due to the geographic and mental distance.

4.2 Robustness of the baseline results

To check the robustness of the baseline results presented above, we employ the following four alternative specifications. First, our sample contains many observations that report zero R&D expenditure in the parent firm and/or overseas subsidiaries. We suspect that the zero R&D expenditure reported by some firms does not mean that their actual R&D expenditure is zero but that those firms are reluctant to report true R&D expenditures due to the costs that would be involved in collecting such data. Therefore, we include as regressors two dummies, one that takes one if the R&D expenditure of the parent firm is zero and another that takes one if the total R&D expenditure of the parent firm's overseas subsidiaries is zero. We assume that these dummies are endogenous in the system GMM estimation.[17]

The results from this alternative specification using the system GMM and presented in columns 1-3 of Table 4 are very similar to the baseline results shown in Table 3, confirming our conclusions above. In addition, the coefficients on the zero R&D dummies are mostly positive and significant, suggesting that some of the MNEs that report zero for their home and overseas R&D expenditure do in fact conduct R&D.

Second, we employ an alternative measure of TFP derived from the methodology developed by Buettner (2003) who incorporates R&D investment into Olley and Pakes's (1996) approach. The latter has been used by Keller and Yeaple (2003) and Javorcik (2004) to test for the presence of knowledge spillovers from FDI, while Buettner's (2003) methodology has been used by Griffith, Harrison, and Van Reenen (2006) to examine spillovers from foreign R&D. Buettner's (2003) approach can be summarized as follows: to compute the TFP level, he assumes a Cobb-Douglas production function and estimates the elasticities of capital and labor, correcting for biases due to the endogeneity of inputs and assuming productivity improvements through R&D activities (see Appendix B for details).

An advantage of this methodology is that we do not need to assume constant returns to scale in production or perfect competition, assumptions underlying the construction of the multilateral TFP index used in our baseline estimation. However, the assumption of constant returns to scale is likely to hold in our dataset, since the elasticities of capital and labor estimated by Buettner's (2003) method are 0.271 and 0.737, respectively. In addition, the growth rate of the TFP index used in the baseline regression and the growth rate of the alternative measure of TFP computed from Buettner's method are very close to each other: the correlation coefficient between the two is 0.99. Accordingly, the GMM results using the alternative measure of TFP presented in columns 4-6 of Table 4 correspond closely to the

[17] This type of dummy for zero R&D expenditure was also used in Griffith, Harrison, and Van Reenen (2006) as a robustness check.

baseline results.[18]

Third, we experiment with three alternative classifications of overseas innovative and adaptive R&D to alleviate possible arbitrariness in the baseline classification, in which we defined basic and applied research and development for the world market as innovative R&D and development for the domestic market and design as adaptive R&D. We first restrict the definition of innovative R&D activities to only basic and applied research, excluding development for the world market. Second, as explained in Section 3.2, some overseas subsidiaries did not report the type of their R&D activities so that the R&D expenditures of these subsidiaries were not counted as either innovative or adaptive R&D expenditure. The average R&D expenditure of such subsidiaries was relatively small, 31.3 million yen, as compared with 106.2 million yen for overseas subsidiaries performing innovative R&D according to the baseline definition and 49.3 million yen for those performing adaptive R&D. In our alternative classification, we categorize overseas subsidiaries that did not report the type of their R&D activities as performing adaptive R&D. Finally, we assume that any overseas R&D activity performed outside the United States, the technology frontier country, is adaptive R&D. Accordingly, about two-thirds of overseas subsidiaries previously defined as performing innovative R&D are redefined as performing adaptive R&D. The mean and the standard deviation of the overseas innovative and adaptive R&D intensity according to the three alternative classifications are shown in Table 5. The results from these alternative classifications are shown in Table 6 and are qualitatively the same as, and quantitatively similar to, the baseline results in Table 3.

4.3 Differences between high- and low-technology industries

As we showed in Section 3.3, there are large differences in the size of overseas R&D between the five high-technology industries (chemicals, machinery and equipment, electrical machinery and electronics, transportation equipment, and precision instruments) and the other, low-technology industries. Therefore, we also estimate the effect of overseas R&D for each of the two types of industries separately.

An advantage of distinguishing between the two types of industries is that by doing so, we can account for possible differences in the ratio of R&D stocks to value added between the two. As we argued in Section 2.1, the derivation of equation (4) from (3) requires the assumption that the ratio of R&D stocks to value added is constant across firms. However, it is likely that the ratio for high-technology industries is different from that for low-technology industries, and hence the baseline results from the whole sample may be biased.

[18] As a further robustness check, we drop firms in the chemical industry, the most R&D-intensive industry according to Table 1, from the sample, finding that this modification does not lead to different results.

The GMM results of the separate estimations for the high- and the low-technology industries are presented in columns 1-3 and 4-6 of Table 7. The results for the high-technology industries are mostly similar to the baseline results for the whole sample reported in Table 3: overseas innovative R&D improves the TFP growth of parent firms, while overseas adaptive R&D does not. Moreover, we do not observe any indirect effect even in the high-technology industries. In contrast, the results for the low-technology industries show that neither innovative nor adaptive overseas R&D has a significant effect on parent firms' TFP growth. Therefore, it seems that the positive effect of overseas innovative R&D on home TFP growth that we have found so far is in fact limited to the high-technology industries, where the size of overseas R&D is larger than in the other, low-technology industries.

5 Conclusion

This paper investigated the impact of overseas subsidiaries' R&D activities on parent firms' TFP growth using firm-level panel data for Japanese MNEs for the period 1996–2002. Distinguishing between overseas innovative R&D (basic research, applied research, and development for the world market) and overseas adaptive R&D (development for the domestic market and design), we found that overseas innovative R&D in high-technology industries raises parent firms' TFP growth, while overseas adaptive R&D has no such effect. In addition, we found that overseas innovative R&D does not improve the impact of home R&D on home TFP growth, or the rate of return on home R&D.

Based on these results, we conclude that overseas innovative R&D activities by Japanese MNEs contribute to productivity growth of parent firms through the utilization of the fruits of overseas R&D in home production activities. However, since overseas innovative R&D does not improve the rate of return on home R&D, overseas innovative R&D does not result in the transfer of knowledge from overseas R&D to the parent firm. These results indicate that it is necessary to distinguish both between overseas innovative and adaptive R&D activities and between the direct and the indirect effect of overseas R&D in order to clarify how the rapidly growing R&D activities of foreign subsidiaries affect parent firms.

Our findings suggest that although current overseas R&D by Japanese MNEs is substantially smaller in magnitude than that by U.S. or European MNEs,[19] Japanese MNEs in high-technology industries may be able to accelerate TFP growth by engaging more in overseas R&D. In addition, our findings imply that Japanese MNEs could benefit even more

[19] The ratio of R&D expenditure by the foreign affiliates of MNEs to the total R&D expenditure of those MNEs was 4 percent in 2002 in the case of Japanese firms, while the corresponding figures for the United States and Sweden were 13 percent and 43 percent, respectively (UNCTAD, 2005).

from overseas R&D by enhancing the interaction between home and overseas R&D. However, these implications may have to be viewed with caution since our analysis is based on the estimation of a production function and ignores general-equilibrium effects of overseas R&D, such as effects on the size of home R&D and the cost of home R&D.

Appendix A: Data and Variables

This appendix provides supplementary information on the construction of our dataset.[20] To construct the real values of output, intermediate inputs, capital stocks, labor inputs, and R&D expenditure of parent firms in Japan, we use firm-level data from the *Kigyo Katsudo Kihon Chosa* (KKKC, Basic Survey of Enterprise Activities) and industry-level data from the Japan Industry Productivity (JIP) Database 2006. The JIP Database 2006 was created as part of the Research Institute of Economy, Trade and Industry (RIETI) research project "Study on Industry-Level and Firm-Level Productivity" headed by Kyoji Fukao of Hitotsubashi University. The JIP Database 2006 is an update of the 2003 version of the database that was constructed by Fukao and others for the period 1970-1998. The updated JIP Database includes various data items for the period 1970-2002 at the 3-digit industry level, including price deflators for output, intermediate inputs, and capital goods as well as input-output matrices. The complete database is available at the RIETI website (http://www.rieti.go.jp).

Real output is defined as nominal total sales reported in the KKKC deflated by the output deflator at the 3-digit level taken from the JIP Database. The nominal value of intermediate inputs is defined as the costs of goods sold plus selling, general, and administrative expenses minus labor costs and the value of depreciation. The nominal value of intermediate inputs is deflated by the intermediate-goods deflator, which is also taken from the JIP Database. Real value added is defined as real output less the real value of intermediate inputs.

Firms' real capital stock represents the real value of the stock of tangible fixed assets *excluding* land, since the book value of land may not reflect its true value. This is particularly the case if the land was purchased a long time ago. In the KKKC, data on the value of land owned by each firm, however, are available only for 1995 and 1996. On the other hand, information on the total value of tangible fixed assets *including* land is available for all years. Therefore, we estimate the nominal value of the tangible fixed assets excluding land of firm i in industry j in year t, $nomK_{ijt}$, by multiplying the firm's total tangible assets including land by one minus the average share of the value of land in total tangible fixed assets in industry j in 1995 and 1996. Then we derive the real capital stock of firm i in industry j in year t, K_{ijt}, from $nomK_{ijt}$, using the industry total of nominal tangible fixed assets excluding land, $nomK_{jt} = \sum_{i \in j} nomK_{ijt}$, and the estimated real value of the corresponding variable, K_{jt}, taken from the JIP Database: $K_{ijt} = nomK_{ijt} \times \frac{K_{jt}}{nomK_{jt}}$. More

[20] When importing raw datasets, we heavily relied on Stata programs written by Toshiyuki Matsuura for Matsuura (2004).

specifically, K_{jt} is obtained by the perpetual inventory method, using industry-level data on fixed capital formation during the period 1975-2002 and industry-level data on fixed assets in 1975.

Labor inputs are measured on a man-hour basis. However, since information on working hours for each firm is not available in the KKKC, we use the industry average of working hours taken from the JIP Database.

The R&D expenditure of each parent firm is deflated by the industry price deflator for intermediate inputs. The nominal value of the R&D expenditure of each overseas subsidiary in Japanese yen is reported in the *Kaigai Jigyo Katsudo Kihon Chosa* (KJKKC, Basic Survey of Overseas Business Activities). We use the PPP real exchange rate taken from the Penn World Tables 6.1 to obtain the real value of overseas R&D expenditure. We aggregate the real R&D expenditure of all overseas subsidiaries of the same parent firm to obtain the real value of the parent firm's overseas R&D expenditure.

We limit our sample to MNEs whose TFP growth and home and overseas R&D expenditure are available for at least three consecutive years. The number of such MNEs is 634. Then, to alleviate biases due to outliers, we drop firms whose ratio of home or overseas R&D expenditure to home value added is among the top 1 percent. The cutoff value is 0.866 for the home R&D intensity and 0.220 for the overseas R&D intensity. This cleaning process results in a sample of 597 MNEs and 2,671 firm-year observations.

Appendix B: Buettner's (2003) Method of Measuring Productivity

Buettner (2003) incorporates R&D investment into Olley and Pakes's (1996) productivity measurement approach and presents several alternative methods. In what follows, we explain the particular type of method adopted in this paper, which assumes no exit of firms (type "k" in his notation).

We begin with the following Cobb-Douglas production function:

$$y_{it} = \beta_0 + \beta_K k_{it} + \beta_L l_{it} + \omega_{it} + \eta_{it}, \tag{7}$$

where ω_{it} represents the productivity level of firm i at time t and η_{it} is a productivity shock or measurement error. It is assumed that the distribution of ω_{it} is governed by a single parameter, ψ_{it}. At the beginning of time $t+1$, firm i observes k_{it} and ω_{it} and chooses $\psi_{i,t+1}$. This choice requires R&D investments of $RD_{i,t+1} = RD(\psi_{i,t+1},\ \omega_{it})$, where $\partial RD/\partial\psi > 0$ and $\partial RD/\partial\omega < 0$. In other words, the distribution of productivity in the next period is a function of the current productivity level and the current R&D investment, while in the Olley-Pakes method, $\psi_{i,t+1}$ equals ω_{it} and does not depend on R&D investment.

Given these assumptions, firm i's optimal choice of investment at time t and thus capital stock in the next period $k_{i,t+1}$ depend on the current productivity level ω_{it} and the current capital stock k_{it}: $\ln I_{it} \equiv i_{it} = i_t(\omega_{it}, k_{it})$, and $k_{i,t+1} = k_{t+1}(\omega_{it}, k_{it})$. The optimal choice of the distribution parameter $\psi_{i,t+1}$ also depends on ω_{it} and $k_{i,t+1}$:

$$\psi_{i,t+1} = \bar{\psi}(\omega_{it}, k_{i,t+1}). \tag{8}$$

We first invert i_t to obtain $\omega_{it} = \tilde{\omega}_{it}(i_{it}, k_{it})$. Substituting this into the production function gives

$$y_{it} = \beta_L l_{it} + \phi_{it}(i_{it}, k_{it}) + \eta_{it},$$

where $\phi_{it} = \beta_0 + \beta_K k_{it} + \omega_{it}$. Semi-parametric estimation of this equation by OLS assuming that ϕ is a polynomial series expansion of the arguments leads to a consistent estimation of β_L.

To estimate β_K in the second stage, we rearrange equation (7) as

$$y_{it} - \beta_L l_{it} = \beta_0 + \beta_K k_{it} + \omega_{it} + \eta_{it}. \tag{9}$$

We assume a Markov process in ω: $\omega_{it} = E[\omega_{it}|\psi_{it}] + \xi_{it} + \eta_{it}$. Thus, equation (9) can be rewritten as

$$y_{it} - \beta_L l_{it} = \beta_0 + \beta_K k_{it} + E[\omega_{it}|\psi_{it}] + \xi_{it} + \eta_{it}. \tag{10}$$

Combining equations (8) and (10), we obtain

$$\begin{aligned} y_{it} - \beta_L l_{it} &= \beta_0 + \beta_K k_{it} + g(\bar{\psi}(\omega_{i,t-1}, k_{it})) + \xi_{it} + \eta_{it} \qquad (11) \\ &= f(\phi_{i,t-1} - \beta_K k_{i,t-1}, k_{it}) + \xi_{it} + \eta_{it}. \end{aligned}$$

We estimate equation (11) by nonlinear least squares, approximating $f()$ by a polynomial series expansion, to obtain a consistent estimate of β_K.

Given consistent estimates of β_K and β_L, we measure the log of the productivity of firm i at time t as $y_{it} - \beta_L l_{it} - \beta_K k_{it}$.

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Table 1: Home and Overseas R&D by Industry and by Year

	Aggregate R&D intensity (%)			
	Home R&D	Overseas R&D	Innovative overseas R&D	Adaptive overseas R&D
Industry (2-digit code)				
Food (12)	6.06	0.18	0.15	0.02
Beverages (13)	12.42	0.05	0.02	0.03
Textiles (14)	13.51	0.81	0.63	0.14
Apparel (15)	4.08	0.07	0.04	0.03
Wood (16)	5.02	0.01	0.01	0.00
Furniture (17)	3.45	0.10	0.03	0.07
Paper (18)	4.83	0.16	0.08	0.03
Publishing and printing (19)	1.23	0.09	0.09	0.01
Chemicals (20)	22.80	2.87	1.02	1.46
Coke and petroleum products (21)	3.05	0.02	0.01	0.00
Plastics (22)	17.91	0.32	0.16	0.08
Rubber (23)	11.40	3.12	2.80	0.04
Other non-metallic mineral products (25)	9.09	0.35	0.25	0.03
Iron and steel (26)	9.26	0.11	0.06	0.04
Non-ferrous metals (27)	14.47	0.50	0.30	0.17
Metal products (28)	11.43	0.86	0.25	0.42
Machinery and equipment (29)	23.80	0.60	0.32	0.10
Electrical machinery and electronics (30)	22.46	1.55	0.87	0.28
Transportation equipment (31)	21.20	1.28	0.60	0.41
Medical, precision and optical instruments (32)	22.12	1.17	0.95	0.05
Other manufacturing industries (34)	14.38	1.26	0.98	0.14
High-technology industries (20, 29-32)	22.46	1.71	0.77	0.61
Low-technology industries (12-19, 21-28, 34)	9.76	0.40	0.27	0.08
Year				
1996	18.47	0.92	0.51	0.32
1997	18.41	1.13	0.60	0.30
1998	19.86	1.44	0.56	0.45
1999	18.04	1.39	0.62	0.48
2000	16.88	1.36	0.66	0.49
2001	19.46	1.48	0.72	0.59
Total	18.46	1.30	0.61	0.44

Notes: This table presents the aggregate R&D intensity by industry, by year, and in total. The aggregate intensity of home and overseas R&D is defined as the ratio of the aggregate R&D expenditure of parent firms and overseas subsidiaries, respectively, to the aggregate value added of parent firms in percentages. Correspondingly, the aggregate intensity of overseas innovative and adaptive R&D is the ratio of aggregate expenditure on overseas innovative and adaptive R&D, respectively, to parent firms' value added. These numbers above are based on 2,671 firm-year observations for Japanese MNEs used in our regression.

Table 2: Summary Statistics

Variable	Description	Whole sample				Sub-sample for firms in high-tech industries		Sub-sample for firms in low-tech industries	
		Mean	S. D.	Min.	Max.	Mean	S. D.	Mean	S. D.
$\Delta \ln TFP$	Growth rate of TFP of the parent firm	0.0231	0.3232	-2.9416	2.0988	0.0358	0.3267	0.0018	0.3161
$R\&D^H/Y$	Ratio of R&D expenditure of the parent firm to its own value added	0.1326	0.1274	0.0000	0.8521	0.1647	0.1390	0.0790	0.0803
$R\&D^O/Y$	Ratio of total R&D expenditure of overseas subsidiaries to value added of the parent firm	0.0096	0.0241	0.0000	0.2192	0.0120	0.0268	0.0057	0.0180
$R\&D^{OI}/Y$	Ratio of innovative R&D expenditure of overseas subsidiaries to value added of the parent firm	0.0059	0.0184	0.0000	0.2192	0.0072	0.0202	0.0038	0.0145
$R\&D^{OA}/Y$	Ratio of adaptive R&D expenditure of overseas subsidiaries to value added of the parent firm	0.0018	0.0098	0.0000	0.1736	0.0025	0.0120	0.0007	0.0035

Table 3: Impact of Overseas R&D on Home TFP Growth: Baseline Results

	Dependent variable: *TFP growth rate*					
	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	OLS	GMM	OLS	GMM	OLS	GMM
Home R&D	0.276	0.873	0.285	0.914	0.288	0.901
	(0.053)**	(0.168)**	(0.053)**	(0.158)**	(0.055)**	(0.175)**
Overseas R&D	0.444	1.468				
	(0.263)	(0.840)				
Overseas innovative R&D			0.338	4.901	0.407	4.389
			(0.340)	(1.323)**	(0.548)	(2.821)
Overseas adaptive R&D			0.239	-5.484	0.236	-5.442
			(0.616)	(3.783)	(0.617)	(3.923)
Home R&D					-0.255	1.511
* *overseas innovative R&D*					(1.604)	(10.016)
No. of observations	2671	2671	2671	2671	2671	2671
R^2	0.114		0.113		0.113	
Hansen J statistic		0.054		0.513		0.473
2nd-order serial correlation		0.647		0.480		0.479

Notes: Standard errors are in parentheses. * and ** denote statistical significance at the 5 and 1 percent levels, respectively. *Home R&D* is the ratio of the parent firm's R&D expenditure to its value added. *Overseas R&D*, *overseas innovative R&D*, and *overseas adaptive R&D* are the ratios of overseas subsidiaries' total, innovative, and adaptive R&D expenditure to the parent firm's value added, respectively. All specifications include year and industry dummies. *P* values are reported for Hansen J statistics and the Arellano-Bond statistics for second-order serial correlation.

Table 4: Results from Alternative Specifications

	Dependent variable: *TFP growth rate*					
	Using dummies for zero R&D expenditure			Using Buettner's (2003) method for the construction of TFP		
	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	GMM	GMM	GMM	GMM	GMM	GMM
Home R&D	0.854	0.882	0.804	0.898	0.911	0.908
	(0.163)**	(0.167)**	(0.188)**	(0.167)**	(0.156)**	(0.168)**
Overseas R&D	1.489			1.400		
	(0.871)			(0.829)		
Overseas innovative R&D		3.990	1.826		4.561	4.373
		(1.502)**	(2.742)		(1.167)**	(2.728)
Overseas adaptive R&D		-1.384	-1.033		-4.749	-4.792
		(3.752)	(3.952)		(3.303)	(3.401)
*Home R&D * overseas innovative R&D*			7.278			0.481
			(10.468)			(9.231)
Dummy for zero home R&D	0.102	0.107	0.098			
	(0.033)**	(0.034)**	(0.035)**			
Dummy for zero overseas R&D	0.036	0.046	0.038			
	(0.019)	(0.022)*	(0.022)			
No. of observations	2671	2671	2671	2671	2671	2671
Hansen J statistic	0.316	0.529	0.562	0.068	0.593	0.546
2nd-order serial correlation	0.680	0.585	0.550	0.573	0.418	0.420

Notes: Standard errors are in parentheses. * and ** denote statistical significance at the 5 and 1 percent levels, respectively. *Home R&D* is the ratio of the parent firm's R&D expenditure to its value added. *Overseas R&D*, *overseas innovative R&D*, and *overseas adaptive R&D* are the ratios of overseas subsidiaries' total, innovative, and adaptive R&D expenditure to the parent firm's value added, respectively. *Dummy for zero home R&D* and *Dummy for zero overseas R&D* are dummy variables that take one if R&D expenditure of parent firms and overseas subsidiaries, respectively, is zero. All specifications include year and industry dummies. *P* values are reported for Hansen J statistics and the Arellano-Bond statistics for second-order serial correlation.

Table 5: R&D Intensity According to Alternative Classifications of Overseas R&D

	Baseline classification		Alternative classification					
			(1)		(2)		(3)	
Definition of overseas innovative R&D	Basic and applied research and development for the world market		Basic and applied research		Basic and applied research and development for the world market		Basic and applied research and development for the world market performed in the U.S.	
Is unclassified R&D defined as adaptive R&D?	No		No		Yes		No	
Variable	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
$R\&D^{OI}/Y$	0.0059	0.0184	0.0049	0.0170	0.0059	0.00184	0.0028	0.0119
$R\&D^{OA}/Y$	0.0018	0.0098	0.0027	0.0116	0.0036	0.0147	0.00473	0.0156

Table 6: Results from Alternative Classifications of Overseas R&D

	Dependent variable: *TFP growth rate*					
	(1)	(2)	(3)	(4)	(5)	(6)
Definition of overseas innovative R&D	Basic and applied research		Basic and applied research and development for the world market		Basic and applied research and development for the world market performed in the U.S.	
Is unclassified R&D defined as adaptive R&D?	No		Yes		No	
Estimation method	GMM	GMM	GMM	GMM	GMM	GMM
Home R&D	0.870	0.844	0.909	0.906	0.911	0.895
	(0.157)**	(0.172)**	(0.161)**	(0.161)**	(0.144)**	(0.182)**
Overseas innovative R&D	4.699	3.450	4.831	4.660	2.864	4.817
	(1.912)*	(4.258)	(1.685)**	(4.017)	(1.340)*	(1.749)**
Overseas adaptive R&D	-2.292	-1.999	-1.876	-1.895	0.026	0.240
	(2.304)	(2.444)	(1.350)	(1.785)	(0.956)	(1.269)
*Home R&D * overseas innovative R&D*		3.887		0.398		-7.232
		(13.050)		(11.989)		(4.654)
No. of observations	2671	2671	2671	2671	2671	2671
Hansen J statistic	0.210	0.187	0.333	0.303	0.552	0.239
2nd-order serial correlation	0.555	0.548	0.476	0.478	0.618	0.657

Notes: Standard errors are in parentheses. * and ** denote statistical significance at the 5 and 1 percent levels, respectively. *Home R&D* is the ratio of the parent firm's R&D expenditure to its value added. *Overseas R&D*, *overseas innovative R&D*, and *overseas adaptive R&D* are the ratios of overseas subsidiaries' total, innovative, and adaptive R&D expenditure to the parent firm's value added, respectively. All specifications include year and industry dummies. *P* values are reported for Hansen J statistics and the Arellano-Bond statistics for second-order serial correlation.

Table 7: Results for High- and Low-Technology Industries

	Dependent variable: *TFP growth rate*					
	High-technology industries			Low-technology industries		
	(1)	(2)	(3)	(4)	(5)	(6)
Estimation method	GMM	GMM	GMM	GMM	GMM	GMM
Home R&D	0.765	0.814	0.816	1.731	1.777	1.722
	(0.183)**	(0.176)**	(0.195)**	(0.306)**	(0.333)**	(0.343)**
Overseas R&D	2.374			0.758		
	(1.204)*			(0.840)		
Overseas innovative R&D		5.316	5.480		0.987	-1.051
		(1.465)**	(3.387)		(1.135)	(1.713)
Overseas adaptive R&D		-2.069	-2.001		0.492	3.721
		(3.758)	(3.701)		(7.313)	(8.600)
Home R&D * *overseas innovative R&D*			-0.549			30.232
			(9.135)			(26.339)
No. of observations	1671	1671	1671	1000	1000	1000
Hansen J statistic	0.116	0.316	0.295	0.692	0.629	0.666
2nd-order serial correlation	0.517	0.399	0.406	0.952	0.958	0.885

Notes: Standard errors are in parentheses. * and ** denote statistical significance at the 5 and 1 percent levels, respectively. *Home R&D* is the ratio of the parent firm's R&D expenditure to its value added. *Overseas R&D*, *overseas innovative R&D*, and *overseas adaptive R&D* are the ratios of overseas subsidiaries' total, innovative, and adaptive R&D expenditure to the parent firm's value added, respectively. All specifications include year and industry dummies. *P* values are reported for Hansen J statistics and the Arellano-Bond statistics for second-order serial correlation. High-technology industries comprise the following industries: chemicals, machinery and equipment, electrical machinery and electronics, transportation equipment, and precision instruments.