G-SEC WORKING PAPER No.10

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November, 2006

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Keywords: R&D, technology transfer, multinational firms

JEL codes: F23, O32, O33

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R&D in foreign affiliates and technology transferred from their parent firms are important potential drivers of productivity in host countries. In this paper we examine the simultaneous impact of local R&D and intra-firm international technology transfer on productivity growth in foreign affiliates. We estimate a dynamic productivity model on a large sample of Japanese manufacturing affiliates worldwide in 1996-1997 and 1999-2000. We find that both affiliate R&D and intra-firm technology transfer contribute to productivity growth, while technology transfer exhibits decreasing marginal returns. The two sources of technology are complements: use of one source of technology increases the marginal impact of the other.

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Acknowledgements: This research is part of the research project on “Global Innovation Systems” of the Global Security Research Institute (G-SEC) at Keio University. Part of this research was conducted while Rene Belderbos was visiting G-SEC at Keio University. The authors thank the statistics office of the Ministry of Economy, Trade and Industry for its permission to access microdata on overseas affiliates.

1. Introduction

There is increasing interest both among researchers and policy makers in international technology transfer and overseas R&D undertaken by multinational firms (e.g. Branstetter et al., 2006). The introduction of new and improved technologies through intra-firm international knowledge transfer and the adaptation and augmentation of these technologies through local R&D activities are essential for the competitiveness of foreign affiliates of multinational firms. They are expected to positively impact the host country economy through increased productivity and potential technology spillovers to local firms.

Although a large number of studies have examined the determinants of R&D in overseas affiliates of multinational firms (e.g. Belderbos, 2001; 2003; Kuemmerle, 1999; Zedtwitz and Gassman, 2002; Odagiri and Yasuda, 1996; Zejan, 1990; Kumar, 1996) as well as those of international technology transfer (e.g. Grubert, 1998; Smith, 2001; Yang and Maskus, 2000; Smarzynska, 2004; Wakasugi and Ito, 2005; Branstetter et al, 2006), few studies have examined the economic impact of technology transfer and R&D on host country operations. Recent studies of international R&D have instead focused on the impact of overseas R&D on the productivity of home country (R&D) activities (e.g. Iwasa and Odagiri, 2004; Griffith et al, 2003; Fors, 1996; Todo and Shimizutani, 2005) [1], while the impact of international technology transfer through licensing has only been examined in the context of local firms in developing countries (Basant and Fikkert, 1996; Braga and Wilmore, 1991; Branstetter and Chen, 2006).

[1] Fors (1996) and Todo and Shimizutani (2005) also found a positive impact of parent R&D on the productivity of overseas operations, but did not examine the impact of international technology transfers.

In this paper, we examine the simultaneous impact of local R&D and intra-firm international technology transfer on productivity growth in foreign affiliates, as well as the potential complementarity or substitutability between these two sources of technology. Consideration of both sources is important as host countries' tax and trade policies may be directed to reduce technology imports with the purpose of stimulating local R&D. An earlier study at the industry level by Hines (1995) found that higher withholding taxes were associated with lower technology royalty payments and higher levels of local R&D, which suggested a possible substitutability between technology adapted or created through local R&D and technology created and transferred by the parent. On the other hand, one may expect a complementary relationship to exist if local R&D enhances the 'absorptive capacity' (Cohen and Levinthal, 1989) of affiliates to effectively introduce new parent technologies.[2] The issue of possible substitutability or complementarity between technology imports and in-house R&D has been the subject of empirical investigation, but previous studies have focused on the performance effects for local firms in developing countries (e.g. Deolalikar and Evenson 1989; Braga and Willmore 1991; Basant and Fikkert, 1996) in the context of restrictive technology import policies.[3]

This paper is the first comprehensive empirical study of the productivity effects of intra-firm international technology transfer and affiliates R&D. We derive our econometric

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[2] Complementarity (see e.g. Milgrom and Roberts, 1990) is understood in this context to exist if the implementation of one 'practice' (e.g. R&D) increases the marginal return to another 'practice' (e.g. technology imports).

[3] Basant and Fikkert (1996) found substitution between R&D and expenditures on imported licenses for Indian firms, while earlier work by Deolikar and Evanson (1989) had suggested complementarity.

specification from an augmented Cobb Douglas production function including interactions between technology transfer and affiliate R&D in the augmentation of the knowledge stock. The model also takes into account potential productivity convergence by including lagged productivity levels. We estimate the dynamic productivity model on a large sample of Japanese manufacturing affiliates worldwide in 1996-1997 and 1999-2000.

This paper is organized as follows. In the next section we present the modeling framework. Section 3 describes the data set and variable construction. Section 4 presents the estimation results and we conclude in section 5.

2. A Model of Productivity Growth

We use an augmented Cobb Douglas framework to model the manufacturing activities of foreign affiliates:

$$Y_{it} = C_{it}^{\alpha} L_{it}^{\beta} K_{it}^{\gamma} e^{\sigma_{it}} \quad (1)$$

where *Y* is value added of affiliate firm *i* at time *t*, *L* is the labor input, *C* is the physical capital stock and *K* is the knowledge stock. α , β and γ are elasticities with respect to physical capital, labor and the knowledge stock, respectively. The parameter σ is a time variant and affiliate-specific efficiency parameter. Dividing both sides by labor, taking the log and differencing the resulting equation in the two consecutive periods, we obtain the equation in its growth form:

$$\Delta q_{it} = (\beta - 1)\Delta l_{it} + \alpha \Delta c_{it} + \gamma \Delta k_{it} + \Delta \sigma_{it} \qquad (2)$$

where $\Delta q_{it} = \log(Y_{it}) - \log(L_{it})$ denotes the growth in labor productivity, with lower case letters denoting variables in natural logarithms. In equation (2) fixed firm differences in productivity are eliminated from $\Delta \sigma_{it}$, but we assume that the change in firm-specific efficiency levels is a function of past productivity:

$$\Delta \sigma_{it} = \theta q_{it-1} + \lambda_t + \varepsilon_{it} \qquad (3)$$

where λ_t is a year-specific intercept and ε_{it} is a serially uncorrelated error term. This specification allows for gradual convergence in efficiency levels between firms, which has been observed to be important in the empirical productivity literature (Klette, 1996; Blundell and Bond 2000; Belderbos et al., 2006).[4] Firms that are behind the productivity frontier are more likely to be able to record strong productivity growth by catching up with productivity leaders. We expect θ to fall within the interval [-1,0]. If θ is zero there is no gradual convergence between leading firms and lagging firms; if θ is –1 complete convergence materializes in one period.

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[4] Klette (1996), for instance, shows that the empirically observed persistent productivity differences between firms require a model specification that allows for gradual convergence.

We transform the knowledge stock portion of the specification (cf. Griffith et al., 2003, p.7; Jones, 2002, p. 233; Fors, 1996) as follows:[5]

$$\gamma \Delta k_{it} \approx \frac{\partial Y}{\partial K} \frac{K_{t-1}}{Y_{t-1}} \frac{\Delta K}{K_{t-1}} \approx \varphi \frac{\Delta K_{it}}{Y_{t-1}} \qquad \text{with } \varphi = \frac{\partial Y}{\partial K} \tag{4}$$

The change in the knowledge capital stock is taken as a function of both technology transfer from the parent firm (I_{it-1}^{lic}) and R&D investments in the affiliate ($I_{it-1}^{R\&D}$):

$$\Delta K_{it} = f(I_{it-1}^{R\&D}, I_{it-1}^{lic}) \tag{5}$$

We approximate the unknown function (5) with a second-order polynomial in R&D investment and technology transfer.[6] If the depreciation rate of the knowledge stock is small[7] we can write:

$$\gamma \Delta k_{it} = \varphi[\eta_1 I_{it-1}^{R\&D} + \eta_2 I_{it-1}^{lic} + \eta_3 (I_{it-1}^{R\&D})^2 + \eta_4 (I_{it-1}^{lic})^2 + \eta_5 (I_{it-1}^{R\&D})(I_{it-1}^{lic})] / Y_{it-1} \tag{6}$$

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[5] This assumes that the ratio of the net investment in knowledge to the knowledge stock is small: $\Delta k_{it} = \ln(1 + \Delta K_{it} / K_{it-1}) \approx \Delta K_{it} / K_{it-1}$.

[6] See Belderbos et al. (2006). This is similar to adopting a Generalized Leontief Linear functional form (e.g. as in Basant and Fikkert, 1996).

[7] Higher depreciation rates lead to an upward bias of the estimate on the rate of return (Mairesse and Sassenou, 1991). We could expand the approximation of changes in the knowledge stock by including more lags of R&D; findings in previous studies, e.g. Hall et al. (1986) and Klette and Johanson (1998), suggest that the most significant effect of R&D on productivity occurs with a one-year lag.

Hence the equation includes linear terms, quadratic terms, and the interaction term between R&D and the transferred technology. Although in previous research the quadratic terms have often been suppressed (e.g. Basant and Fikkert, 1996), inclusion of the quadratic terms can be essential. If the process of augmentation of the knowledge capital stock is characterized by decreasing returns to scale and if the most R&D intensive firms engage in both internal R&D and technology imports, the interaction term between R&D and technology transfer may be confounded as negative as it picks up the declining marginal impact of R&D or technology transfer. A full specification with quadratic terms is required to explore this. In the empirical analysis, we will estimate the productivity effects of R&D and technology transfer using (6). In order to show the importance of using a more general specification, we will also report the results of models with quadratic terms suppressed.

Combining equations (2), (3), and (6) and bringing the lagged productivity term to the right hand side, we arrive at the dynamic equation:

$$q_{it} = (1+\theta)q_{it-1} + (\beta - 1)\Delta l_{it} + \alpha \Delta c_{it} + \varphi[\eta_1 I_{it-1}^{R\&D} + \eta_2 I_{it-1}^{lic} + \eta_3 (I_{it-1}^{R\&D})^2 + \eta_4 (I_{it-1}^{lic})^2 + \eta_5 (I_{it-1}^{R\&D})(I_{it-1}^{lic})] / Y_{it-1} + \lambda_t + \varepsilon_{it} \qquad (7)$$

3. Data, Variables, and Descriptive Statistics

The data on which we estimate the model concern Japanese overseas manufacturing affiliates and are collected by the surveys of Overseas Business Activities conducted by the

Japanese Ministry of Economy, Trade and Industry. We could access the (three-yearly) Basic Surveys of Overseas Business Activities in 1996 and 1999 and the shorter Trend Surveys of Overseas Business Activities carried out in 1997 and 2000 (MITI, 1997, 2000). The data represent the accounts for previous fiscal years ending in March. Since only the Basic Surveys contain information on technology payments and fixed capital, the data do not allow for the creation of a full panel data set. Instead, we match the basic survey data at the affiliate level with the trend survey in the following year to establish productivity, employment and capital stock growth, while we pool over the years 1996-1997 and 1999-2000. Although the surveys include a large number of manufacturing affiliates, affiliates frequently are not included in the surveys of consecutive years. In addition, the questions on technology payments and R&D suffer from low response rates. We cross-checked the reliability of the data by comparing R&D and technology payment data with other entries such as the range of functional activities of the affiliate (which may include R&D), the number of reported R&D employees, and answers to similar questions for the same affiliates in earlier or later years. This to ensure that a zero was not mistaken for a missing value - a distinction which is sometimes not properly made in the surveys. As a result, we could draw on 1,798 observations on affiliates with accurate information on the variables of interest. The dataset includes 920 affiliates in 1996-1997 and 878 affiliates in 1999-2000. The affiliates are located in 38 countries.

R&D is the affiliate's expenditure of R&D as reported in the basic survey. Our proxy for technology transfer is the value of licensing and royalty payments to the parent firm as reported by the affiliate. The reported value of these technology transfer payments may of course be biased if firms engage in transfer pricing to minimize tax payments in the host country, but the reported payments will be highly correlated with the real value of technology transferred to the affiliate.[8] We calculated value added as sales minus the value of procurement of parts and materials.[9] The capital stock in the base year is the book value of fixed tangible assets as reported in the basic surveys. For the following years, we calculate the capital stock as the book value in the preceding year, fixed capital investments in the following year, and depreciation, with the depreciation rate set at 0.0792[10]. We expressed all values in 1999 prices by applying the GDP deflator reported in the World Development Indicators and the Yen-local currency exchange rate as reported in the METI surveys.

In total, the sample includes 86 billion Yen in affiliate R&D spending and 151 billion Yen in payments for technology transfer. The ratio of R&D to value added is on average 1.6 percent while the ratio of technology payments to value added is higher at 2.7 percent (summary statistics are presented in Table 1). The distribution of affiliates over industries and countries is shown in Tables 2 and 3. The tables also show the average R&D to value added ratio and the technology payments to value added ratio per country and industry. Table 2 shows a concentration of both R&D and technology transfer in specific industries, in particular

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[8] We explored the possible bias due to transfer pricing by allowing the effect of reported technology transfer to differ systematically with the relative effective tax rate of the host country. We did not find evidence that the productivity impact of technology transfer was smaller for higher tax countries, which one would expect if the transfer price in the latter countries is systematically set higher.

[9] This allowed for a substantially more reliable estimate for the affiliates than in case of deriving value added as the sum of wage costs, depreciation costs and net profits. In particular profits figures are severely under-reported in the survey.

[10] We took this figure from Masuda (2000) who arrives at this rate using a perpetual inventory method. Deprecation costs are not well reported in the basic survey and sometime aggregate tangible and intangible assets.

in terms of the value of R&D and technology transfer.[11] R&D and intra-firm technology payments are concentrated in chemicals and pharmaceuticals, general machinery, electrical machinery and transport machinery. The highest R&D intensity is however reported in the precision machinery industry. The ranking of technology transfer intensities is slightly different, with electrical machinery reporting the highest intensity (4.1 percent) followed by chemicals and pharmaceuticals, general machinery, transport machinery and building materials.

The distribution of R&D and technology payments over countries is heavily skewed, as confirmed by earlier studies of Japanese overseas R&D (e.g. Belderbos, 2003; Todo and Shimizutani, 2005, Iwasa and Odagiri, 2004). The United States is responsible for half of the R&D expenditures of the firms in the sample, and about a third of the value of technology transfers. R&D also takes place in Asian affiliates (China, Korea, Singapore) at a scale comparable to affiliates in Europe, but the value of R&D relative to value added is much lower in Asian affiliates, with the exception of Korea. Affiliates in France[12] have the highest R&D intensity (7.2 percent) followed by US affiliates (3.3) and affiliates in smaller European countries. In terms of the importance of technology payments, US and European affiliates report intensities that are broadly similar to R&D. Asian affiliates show substantially higher intensities relative to R&D at 3-4 percent, again with the exception of Korea.

The concentration of R&D and technology transfer in specific industries and countries is partly a feature of the technology intensity of industries and countries, but also suggests that

[11] A similar pattern is observed for R&D and technology imports in Taiwan (Branstetter and Chen, 2006).

[12] The relative high average R&D to value added ratio of French affiliates is mostly due to a high ratio for one specific affiliate.

multinational firms jointly 'adopt' the practices of technology transfer and R&D in their affiliates, which is indicative of a complementary relationship. We investigate this issue in the next section.

4. Empirical Results

The estimation results for equation (7) are presented in Table 4 (robust standard errors are given in parenthesis). Column (1) presents the estimates from a specification restricting $\eta_2 = \eta_4 = 0$, hence excluding quadratic terms, and column (2) presents the results for the full model. Both models include a set of 2-digit industry dummies, country dummies, and a year dummy. The models explain more than 85 percent of the variation in productivity. The estimated coefficients on the lagged dependent variable imply a convergence parameter θ of --0.28, suggesting that about a fourth of the productivity lead is neutralized by the next period.[13] The growth of employment and capital stock variables are significant and imply an elasticity of 0.26 for labor and 0.12 for fixed capital.[14] Both models show that R&D and technology payments add to productivity growth. In model 1, the estimated rate of return on R&D ($\varphi\eta_1$) is 0.54 and the return on licensing ($\varphi\eta_3$) is higher at 0.76. This pattern confirms earlier results and is partly explained by the more 'ready to use' character of technologies

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[13] Previous studies using GMM techniques (e.g. Blundell and Bond, 2000; Klette, 1996) find similar values for the lagged productivity term in production function equations.

[14] These elasticities compare well with the estimates for Taiwanese firms reported in Branstetter and Chen (2006).

developed by the parent firm versus the more uncertain outcome of local R&D efforts. The interaction effect between R&D and technology payments has a positive sign but is not significantly different from zero. When the full model in (2) is estimated including the quadratic terms of R&D and technology payments, this changes. The interaction effect between R&D and technology payments is now significantly positive, demonstrating the importance to adopt a full specification of knowledge stock augmentation. The square term of technology payments is significantly negative and the square term of R&D is also negative but insignificant.[15] These results suggest that international technology transfer and local R&D are complements: the marginal impact of technology transfer is greater if the affiliate also engages in local R&D and vice versa. At the same time, there are decreasing returns to technology transfer, although the decline in marginal impact only sets in at relatively high levels of the value of technology transfer (close to 1.2 billion Yen). Affiliates benefit more from adding local R&D capability to technology transferred from the parent, rather than sole reliance on the latter. Conversely, local R&D has a smaller impact if conducted without technology transfer from the parent.

5. Conclusions

In this paper we examine the simultaneous impact of local R&D and intra-firm international technology transfer on productivity growth in foreign affiliates and assess the

[15] The insignificant coefficient for the square term of R&D may be related to limited presence in the sample of affiliates with higher R&D intensities.

potential complementarity or substitutability between these two sources of technology. It is the first comprehensive empirical study of the productivity effects of intra-firm international technology transfer and affiliates R&D. We derive the econometric specification from an augmented Cobb Douglas production function including interactions between technology transfer and affiliate R&D in the augmentation of the knowledge stock. The model also takes into account potential productivity convergence through a dynamic specification. We estimate the model on a large sample of Japanese manufacturing affiliates worldwide in 1996-1997 and 1999-2000. The empirical results confirm that both affiliate R&D and intra-firm technology transfer from the parent firm contribute to productivity growth, with technology transfer exhibiting decreasing marginal returns. Furthermore, the two sources of technology are complements: use of one source of technology increases the marginal impact of the other.

While the empirical results are in line with earlier studies that confirmed an independent positive impact of R&D and technology imports (e.g. Branstetter and Chen, 2006, Basant and Fikkert, 1996), the finding of complementarity contrasts with earlier inferences drawing on the correlation between R&D and technology exports at the industry level (Hines, 1995) and studies of productivity growth in independent firms in India (e.g. Basant and Fikkert, 1996). Multinational firms' affiliates benefit more directly from the two sources of technology, as coordination between the parent and affiliate will allow local R&D to be specifically governed to absorb, adapt and build on parent firm technologies. The implication is that local R&D is less efficient and less likely to be performed on a large scale if affiliates face restrictions on the use of parent-developed technologies. Host countries tax and trade policies directed at reducing payments for technology imports are unlikely to serve as an effective tool to stimulate local R&D. They may instead reduce productivity growth with negative consequences for potential spillovers to the local economy and economic growth. Future research could examine this issue more closely and relate technology transfer, R&D, and productivity growth more specifically to host country policies. A parallel line of further research is to examine whether potential complementarity between technology imports and local technology development exists in local firms, using the testing framework proposed in this paper.

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Table 1. Summary Statistics (1,798 observations)

Variable	*Mean*	*Std. Dev*	*Description*
Productivity	1.59	1.38	Growth (Δ log) in value added per employee
Lagged productivity	1.47	1.41	Log value added per employee in previous year
Labor growth	0.03	0.37	Growth (Δ log) in the number of employees
Capital stock growth	0.18	0.40	Growth (Δ log) in the value of fixed tangible assets
R&D	0.016	0.062	Ratio of R&D expenditure over value added in previous year
Technology transfer	0.027	0.068	Ratio of license and royalty payments to parent firm over value added in previous year

Table 2. Distribution of R&D and Technology payments over industries

Industry	# affiliates	R&D / value added (%)	Total R&D (mln. Yen)	Technology payments / value added (%)	Total technology payments
Food and drinks	65	1.0	464	1.4	414
Textiles	133	0.4	1,077	1.4	1,281
Wood and pulp	22	0.8	423	0.5	350
Chemicals and pharmaceuticals	194	3.2	20,928	3.2	16,601
Oil	14	1.4	83	1.3	59
Building materials	58	0.8	2,371	2.6	2,997
Steel	58	0.4	204	0.5	196
Nonferrous metals	46	0.4	743	1.5	928
Metal	36	0.3	103	0.6	107
General machinery	166	1.0	5,410	3.1	14,852
Electrical machinery	517	1.6	30,024	4.1	66,573
Transport machinery	296	1.8	17,841	2.9	44,440
Precision machinery	52	4.8	2,417	1.1	315
Other manufacturing	141	1.0	3,883	1.2	2,363
Total	*1,798*	*1.6*	*85,971*	*2.7*	*151,476*

Table 3. Distribution of R&D and technology payments over countries

Country	# affiliates	R&D / value added (%)	Total R&D (mln. Yen)	Technology payments / value added (%)	Total technology payments
North America					
United States	452	3.3	43,991	2.4	49,303
Canada	27	0.8	189	0.6	784
Mexico	32	0.7	178	3.0	1,709
South America					
Brazil	44	1.0	511	1.1	480
Other countries	12	0.0	2	1.6	495
Asia					
China	311	0.6	2,960	3.1	11,192
Hong Kong	77	0.4	339	3.0	11,986
Korea	107	2.0	2,883	1.3	1,528
Thailand	191	0.3	705	3.8	12,918
Indonesia	124	0.2	96	4.2	8,617
Singapore	145	0.6	3,095	3.1	21,290
Other countries	5	0.3	5	0.6	27
Oceania					
Australia	23	0.3	1,426	1.0	6,931
New Zealand	10	0.5	31	0.1	9
Europe					
Belgium	18	2.1	2,303	2.3	1,363
France	28	7.2	4,367	3.5	4,200
Germany	39	1.4	3,889	1.8	4,619
Italy	14	2.1	2,253	2.0	1,150
Netherlands	19	2.4	9,526	1.3	2,242
Spain	24	2.2	1,350	1.9	1,354
United Kingdom	77	1.8	2,914	1.8	5,273
Other countries	19	2.8	2,958	5.9	4,006
Total	*1,798*	*1.6*	*85,971*	*2.7*	*151,476*

Table 4. Estimation results for equation (7): productivity growth in Japanese affiliates

	Model 1	*Model 2*
Lagged productivity $(1+\theta)$	0.740	0.744
	[0.013]***	[0.013]***
Labor growth $(\beta-1)$	-0.741	-0.741
	[0.035]***	[0.034]***
Capital stock growth (α)	0.121	0.123
	[0.032]***	[0.032]***
R&D ($\varphi\eta_1$)	0.543	0.752
	[0.222]**	[0.265]***
R&D² ($\varphi\eta_2$)		-0.0003
		[0.00022]
Technology transfer ($\varphi\eta_3$)	0.763	0.949
	[0.190]***	[0.205]***
Technology transfer² ($\varphi\eta_4$)		-0.0004
		[0.00019]**
R&D * Technology transfer ($\varphi\eta_5$)	0.00071	0.00129
	[0.00055]	[0.00063]**
Year, Country and Industry fixed effects	Yes	Yes
Constant	0.618	0.603
	[0.047]***	[0.047]***
Observations	1.798	1.798
R^2	0.85	0.86

Notes: robust standard errors in parenthesis; *, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively.