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Abstract:

This paper investigates locational choice of corporate research and development (R&D) activities with Japanese manufacturers' data collected through the *Basic Survey of Japanese Business Structure and Activities*. We first classify companies into four categories according to the types of R&D (internal R&D/external R&D) they conduct, and examine whether firm size, firm age and internal R&D intensity are determinants of R&D locations. We then explore whether these same factors also dictate the extent to which firms utilize external inventive resources. Regression analyses suggest that large firms tend to engage in external R&D to a greater degree, and that both very young and long-established companies reply on R&D outsourcing. It is also found that internal R&D and external R&D complement each other for firms that exploit innovative opportunities inside and outside of the organization.

Keywords: R&D outsourcing, In-house R&D, Firm size, Firm age, Industry

JEL codes: D21, L21, L60

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Outsourcing of Inventive Activities in the Japanese Manufacturing Sector:
Analysis of Firm-Level Data

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1. Introduction

This paper is an attempt to investigate corporate research and development (R&D) activities with a focus on where they take place. Companies have the option of hiring researchers to engage in in-house R&D activities. On the other hand, they can search for R&D resources available in other organizations and outsource R&D operations. This inquiry investigates factors that influence firms' resource allocation between internal R&D and external R&D.[1]

Researchers have studied the link between inventive activities and firm size. Schumpeter (1950) argues that characteristics of R&D, such as uncertainty and economy of both scale and scope, put large firms in an advantageous position in exploiting innovation opportunities. In a survey of innovation literature, Cohen (1995) concludes that firm size is positively correlated with both innovation input and output.[2] Cohen (1995) also finds that innovation input, such as R&D expenditure, increases proportionately with firm size.

While the total R&D could be partly determined by the firm size, the R&D locational choice reflects the dual roles of inventive activities discussed in Cohen and Levinthal (1989). They argue that inventive activities performed within an organization results in generation of new information that leads to creation of novel processes and products. They discuss that internal R&D also serves to improve the firm's capability to assimilate and exploit existing information, which is called the "absorptive" or "learning" capacity. When one regards internal and external R&D operations as substitutes to each other, the locational choice mainly reflects their relative costs. If the "absorptive" capacity of internal R&D is taken into account, however, internal R&D enhances potential benefits derived from external R&D. It then follows that external R&D utilization could increase together with internal R&D efforts.

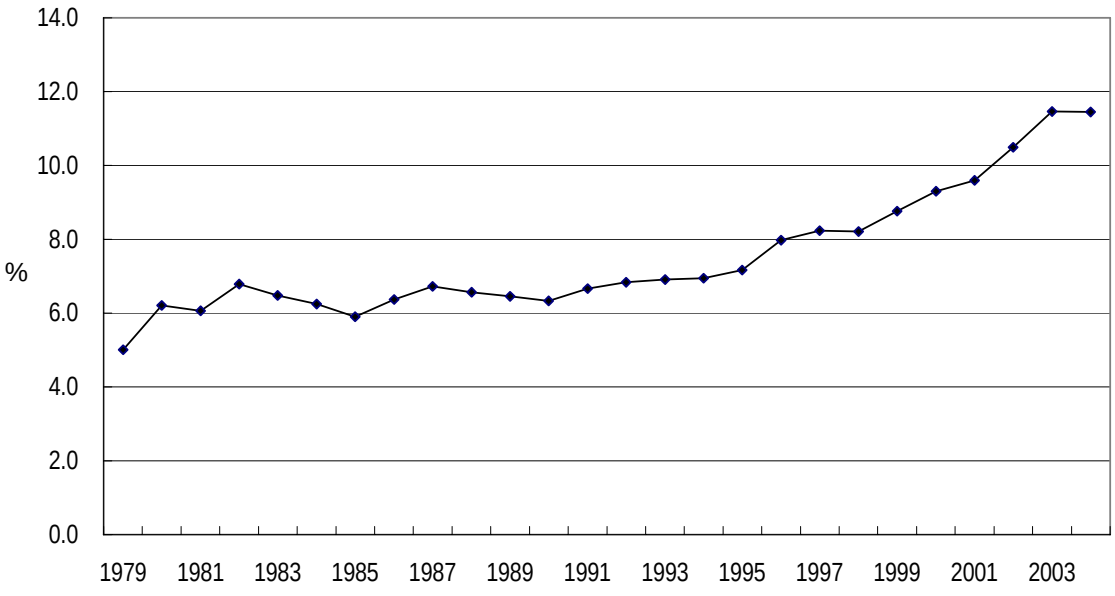
Empirical analyses in this paper will explore corporate efforts to utilize external inventive resources employing data of Japanese companies. The next section provides background information on the Japanese manufacturers as well as the large scale survey that this study uses. The following section presents the econometric results and discusses various findings with their implications. The concluding section summarizes the findings and proposes areas of further research.

2. External R&D by Japanese Manufacturing Companies

Traditionally, Japanese firms conducted most of their R&D within their own organizations. In the past decade, however, their behavior shifted in the direction of greater R&D cooperation with outside organizations. Figure 1 demonstrates this trend in terms of the share of corporate R&D disbursements that fund external R&D activities.[3] The share remained 6-7% in the 1980s and until mid-1990s, and began to increase during the second half of the 1990s to exceed 11% in 2003 and 2004.

This observation merits attention, as it may represent a comprehensive shift in the inter-firm relationship among Japanese companies. Transactions with non-affiliated firms were basically limited to those conducted in the context of the buyer/seller of inputs such as raw materials, intermediate goods, and services. In the process of surviving the post-bubble recession of the 1990s, however, many Japanese companies began to seek inter-firm cooperation as a means to best utilize their resources. The rise of the R&D outsourcing is an example of this effort, and its investigation could lead to a better understanding of the emerging alliance among Japanese companies.

Figure 1. External R&D Activities Share: Japanese Manufacturing Firms, 1979-2004



This paper investigates R&D activities of Japanese manufacturers with their firm-level data. The data for quantitative analyses are from the *Basic Survey of Japanese Business Structure and Activities* (*Kigyo Katsudo Kihon Chosa*, in Japanese)

conducted by the Ministry of Economy, Trade and Industry (METI). METI initiated this exercise in 1992, and has continued it since 1994 as an annual survey to collect wide-ranging information from individual companies. The survey provides a comprehensive dataset for a large number of firms as it covers firms larger than the threshold of 50 employees or 30 million yen of paid-in capital.[4] This research uses data from 1995-2004 surveys that report corporate data of ten fiscal years, 1994-2003. The 10-year panel contains 63,567 observations from 11,663 manufactures.

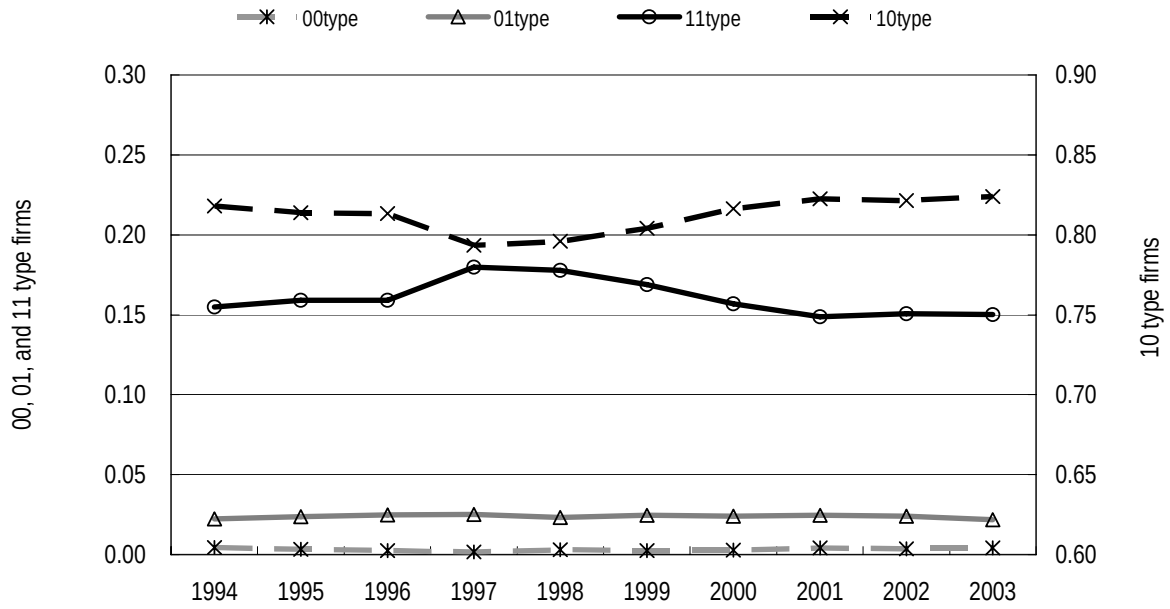
Table 1. R&D/Sales Ratio Mean by R&D Location Category

Category	Sample size	R&D Location	R&D/Sales Mean (Std. Dev.)
Total	63,567	internal	0.0192 (0.0282)
		external	0.0011 (0.0064)
00 type (No R&D activity)	206	N.A.	0
01 type (external only)	1,514	external	0.0092 (0.0169)
10 type (internal only)	51,629	internal	0.0172 (0.0253)
11 type (both activities)	10,218	internal	0.0326 (0.0379)
		external	0.0057 (0.0132)

Table 1 summarizes their internal R&D/sales and external R&D/sales according to firm's R&D location classification for the entire sample. The category 00 represents firms with no innovative activities in terms of internal and external R&D. Firms in category 01 and 10 engage in either of them: the former 01 relies on outsourcing, hence external R&D activities, and the latter 10 conducts internal R&D only. In the other category 11 are included companies that combine internal and external R&D. The table indicates that the share of observations in category 01 and 11 in the total is about 18.5% (11,732 out of 63,567). This implies that the Japanese manufacturers that exploits outside resources for the inventive purposes are still the minorities. Between these two, the ratio of external R&D to sales is higher (0.0092) in the 01 category observations than in category 11 (0.0057) on the average. Those firms that totally rely on external R&D utilize it to a greater extent than the ones that combine internal and external inventive activities. This is in contrast to the comparison between 10 and 11 in terms of their internal R&D use. The category 11 companies engage in internal R&D at the average sales ratio of 0.0326 to combine it with external R&D, which is higher than the exclusively internal, category 10 firms.

Figure 2 depicts the R&D category composition for the 1994-2003 period. The graph shows that the distribution of firms across four categories has been stable. The 10 and 11 type firms have been consistently dominant with the combined share of more

Figure 2. Transition of Distribution by R&D Activities Patterns: 1994-2003

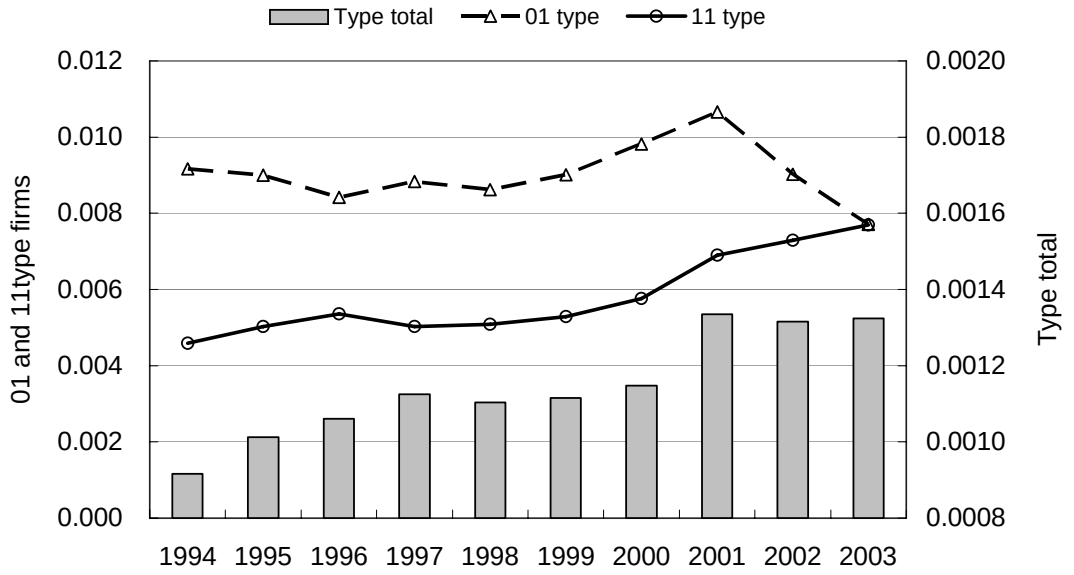


than 95%. Although the category 10 type reduced its share in 1997-1999 with a corresponding increase for the category 11, their respective shares reverted back to the 1994-1996 level in 2000-2003. In order to bring about the acceleration of overall external R&D share (as demonstrated in Figure 1) in the absence of a marked rise in the share of category 01/11 firms that outsource R&D activities, individual firms in these two categories must have expanded R&D outsourcing in the sample period. Figure 3 illustrates this point. The average ratio of external R&D to sales for category 11 firms steadily increased, which led to the rising trend of "Type total" overall R&D ratio.

R&D location pattern for Japanese manufacturers in the past 10 years can be summarized as follows. Between in-house and external, the principal R&D location remains to be the former, while the latter has gradually gained in importance. This has taken place as a result of the more intense use of outside R&D resources by category 11 firms, rather than by the switch of category 10 firms into category 11.

Table A1 in Appendices demonstrates the mean of total (internal plus external) R&D ratio for individual industries by their descending order. It also shows breakdown of individual industry observations to three categories, 01, 10, and 11. The industries that are on the high end of the total R&D ratio ranking tend to have a greater percentage of 11 category firms. For example, the pharmaceutical industry is the most R&D intensive of all, with the average firm R&D ratio being 6.42%. In addition, almost half (48.4%) of their observations belongs to category 11. Three industries next to

Figure 3. Transition of external R&D ratio by firm type



pharmaceuticals on the list, telecommunications, precision machinery, and chemicals, also have category 11 observation shares that exceed 20%, while there are only two (oil & coal and nonferrous metal) among the rest of the industries that reach this percentage.

3. Determinants of External R&D Activities: Location Category and External R&D Size

This section presents empirical analyses of Japanese corporate data, and first examines R&D decision through identification of firm attributes that determine R&D location. This is then followed by the investigation of the degree of external R&D utilization. Combination of these analyses would give us a broad picture of managerial choice, i.e., whether to engage in R&D outsourcing, as well as of its decision on the extent of external R&D utilization.

3. 1. R&D Location Decision

We first analyze a firm's decision to outsource its R&D activities. As the firm's choice is a discrete one, we explore this issue with the probit model by pooling the data as well as by treating them as a panel. Using the firms in the R&D location category 10 (internal R&D only) as the reference group, we examine factors that characterize

companies that rely exclusively on external R&D (category 01) and those that engage in both types of R&D (category 11).[5]

Among the variables that would potentially explain R&D outsourcing decisions is firm size, whose proxy in this paper is the number of employees. If the Schumpeterian hypothesis is correct, large firms devote more resources in innovative activities. Comparison of firm size coefficients in the analysis of category 01 and 11 firms would further provide a clue on whether size also affects R&D location, i.e., internal and external, in a uniform manner. Another explanatory variable is the intensity of R&D activities within the organization, which is represented by internal R&D to sales ratio. To the extent that firm behavior incorporates the "learning" aspect of R&D, the relationship between internal R&D and external R&D is expected to be complementary to each other.

The firm establishment year is also among the independent variables to explore which firms, i.e., young or long-established, are more likely to exploit outside inventive resources. The firm age is relevant in the sense that innovation is a source of firm growth. If there is a relationship between corporate age and firm growth, a firm's R&D behavior is likely to reflect its age.[6] Marshall (1920) hypothesized that growth is negatively correlated with firm age. Jovanovic (1982) offers the "passive learning" model as a theoretical framework, which would predict inverse growth-age relationship. Evans (1987a, 1987b) find that firm growth decreases with firm age and firm size, and thus support Jovanovic hypothesis. If a robust link is identified between firm age and innovation, it would provide a new dimension to the age-growth debate.

Finally, the industry dummies are designed to depict propensities to engage in external R&D that are specific to individual industries. The machinery industry serves as the baseline, since inspection of Table A1 indicates that that its average R&D intensity is close to the overall observation mean, and also that the industry has the largest number of observations across industries.

Regression results are shown in Table 2. The dependent variable for the first two models (pr01 and pp01) is the category 01 firm dummy; the former model pools the 10-year data while the latter uses the random effect specification. The last two models (pr11 and pp11) estimate determinants that place firms in category 11. The results for category 01 imply that large firms do not exclusively rely on external R&D. As the number of employee increases, the tendency to join category 01 diminishes.[7] The combination of establishment year coefficients in the pooled estimate (pr01) indicates that firms tend to be in category 01 at the both ends of the age spectrum. Positive and significant estimates in both pr01 and pp01 for seven industry dummies mean that firms

in these sectors are likely to be found in category 01: They are, oil & coal, nonferrous metals, textile, ceramics, metal, iron & steel, and print industries.

Estimates for category 11 indicate that, the larger a firm's in-house inventive activities, the greater the tendency to engage in external R&D.[8] The probability to use external R&D increases at a decreasing rate up to the point where internal R&D ratio is between 0.30 and 0.32. In view of the sample average total R&D ratio of 0.0204 (Table A1), one can conclude that additional internal R&D efforts lead them to seek for external inventive resources for most firms.

The effect of firm size is totally reversed for category 01. As a firm adds more employees, the probability for a firm to join category 11 increases. The contrast from the results of category 01 implies that expansion of operations would lead companies away from category 01 and bring them into category 11. One can reconcile the opposite 01/11 results based on the link between firm size and internal R&D activities. Large firms are more likely to engage in in-house R&D, which implies that size is associated with both internal and external R&D utilization. Thus, they have the tendency to join category 11 rather than 01.[9]

The coefficients on the establishment year show a similar pattern with that for the category 01 results. Among the industries that are ranked the five most R&D intensive in Table A1 (pharmaceutical, telecommunication, precision, chemical, and electrical), all but telecommunication exhibit positive tendency to fall in category 11. Companies in oil & coal, nonferrous metal, and ceramic industries are estimated to be grouped with category 11 as well as with category 01.

Figures 4a and 4b demonstrate the relationship between firm size and its R&D location category (4a) and between establishment year and category (4b). Over the range that contains most of the sample firms, size effects on the category 01/11 probability are totally opposite. Large firms are less likely to rely exclusively on external R&D (category 01; pp01 and pr01), while they tend to find themselves engaged in both internal and external R&D (category 11; pp11 and pr11). Companies that have been recently established are more likely to be in category 01, and those that have long been in business tend to be in category 11. Figure 4c depicts the association between a firm's internal R&D ratio and its probability to be in category 11. Internal R&D activities tend to induce firms to utilize outside inventive resources within the range relevant for most firms.

Table 2. Determinants of R&D outsourcing execution

Sample ranges	01 and 10 type firms				10 and 11 type firms			
Dependent variable	01 type firm = 1				11 type firm = 1			
Esitimation methods	Probit model (pr01)		Panel probit (pp01)		Probit model (pr11)		Panel probit (pp11)	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Firm_size	-5.1E-05	1.8E-05 ***	-1.6E-04	3.8E-05 ***	1.6E-04	4.9E-06 ***	3.4E-04	1.5E-05 ***
Firm_size (sq)	8.5E-10	2.9E-10 ***	2.7E-09	9.4E-10 ***	-2.6E-09	1.0E-10 ***	-5.0E-09	2.5E-10 ***
Establishment year	-0.456	0.129 ***	-0.026	0.436	-0.325	0.065 ***	-0.751	0.150 ***
Establishment year (sq)	0.000	0.000 ***	0.000	0.000	0.000	0.000 ***	0.000	0.000 ***
Internal R&D ratio					8.830	0.334 ***	8.419	0.807 ***
Internal R&D ratio (sq)					-14.627	1.249 ***	-13.259	2.319 ***
Pharmaceuticals	-0.134	0.113	-0.953	0.389 **	0.843	0.036 ***	1.877	0.146 ***
Telecommunication	0.007	0.090	-0.232	0.216	0.199	0.043 ***	0.142	0.171
Precision machinery	0.003	0.076	0.340	0.229	0.276	0.037 ***	0.632	0.130 ***
Chemical	-0.147	0.062 **	-0.801	0.227 ***	0.382	0.026 ***	0.633	0.087 ***
Electrical	0.017	0.053	-0.058	0.150	0.098	0.028 ***	0.257	0.100 **
Electronics	0.122	0.058 **	0.237	0.205	0.168	0.033 ***	0.155	0.125
Rubber	0.071	0.111	-0.984	0.318 ***	-0.042	0.062	-0.104	0.190
Transportation	0.085	0.054	-0.446	0.226 **	0.071	0.029 **	-0.100	0.100
Oil & coal	1.202	0.101 ***	2.474	0.290 ***	0.629	0.083 ***	1.677	0.224 ***
Nonferrous metal	0.358	0.074 ***	0.800	0.261 ***	0.389	0.043 ***	0.604	0.137 ***
Plastics	0.092	0.061	0.283	0.173	0.039	0.036	-0.065	0.103 *
Textile & clothing	0.368	0.059 ***	0.827	0.194 ***	0.173	0.038 ***	0.183	0.117
Ceramics	0.155	0.065 **	0.661	0.193 ***	0.107	0.038 ***	0.193	0.113 *
Tan & fur	0.201	0.200	0.864	0.582	0.479	0.104 ***	-0.161 .	
Metal	0.135	0.054 **	0.361	0.148 **	0.028	0.032	-0.193	0.105 *
Furniture	0.381	0.087 ***	0.317	0.358	0.390	0.055 ***	0.761	0.134 ***
Drink & tobacco	-0.026	0.107	-1.246	0.381 ***	0.214	0.051 ***	0.214	0.257
Iron & steel	0.451	0.073 ***	1.619	0.217 ***	0.063	0.051	-0.169	0.321
Food	-0.055	0.053	-0.206	0.150	-0.045	0.030	-0.290	0.100 ***
Paper & pulp	0.140	0.087	0.419	0.237 *	-0.169	0.058 ***	-0.454	0.161 ***
Print	0.500	0.079 ***	0.460	0.240 *	-0.149	0.068 **	-0.532	0.188 ***
Wood	0.103	0.148	0.830	0.357 **	-0.435	0.127 ***	-0.713	0.307 **
Others	0.290	0.073 ***	0.452	0.229 **	0.168	0.046 ***	0.212	0.188
Time trend	-0.005	0.004	0.002	0.009	-0.010	0.002 ***	-0.027	0.004 ***
Number of obs	49571		49571		57737		57737	
Log likelihood	-6120		-4055		-23528		-16677	

Notes: Reference group is 10 type (only internal R&D) firms. Base industry is general machinery. Statistical significance; * 10%, ** 5%, *** 1%

Figure 4a. Relation of firm size and firm type

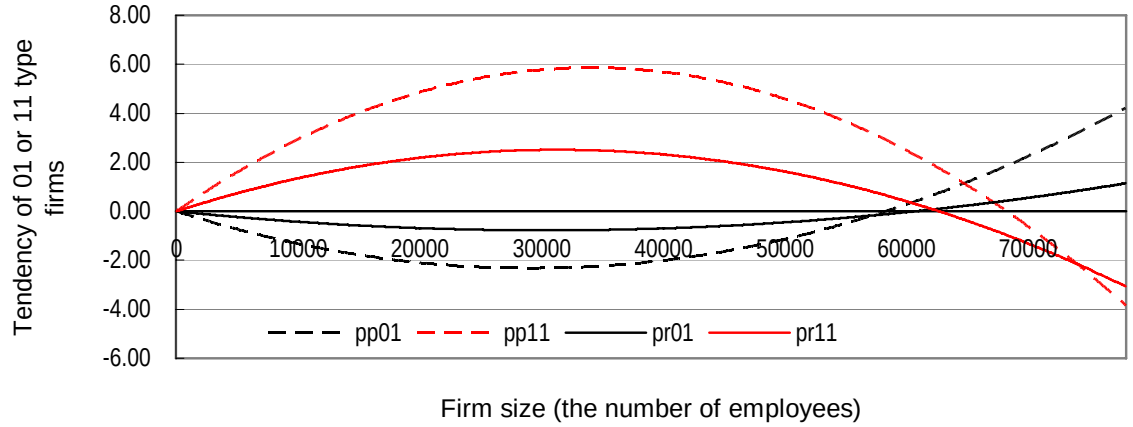


Figure 4b. Relation of establishment year and firm type

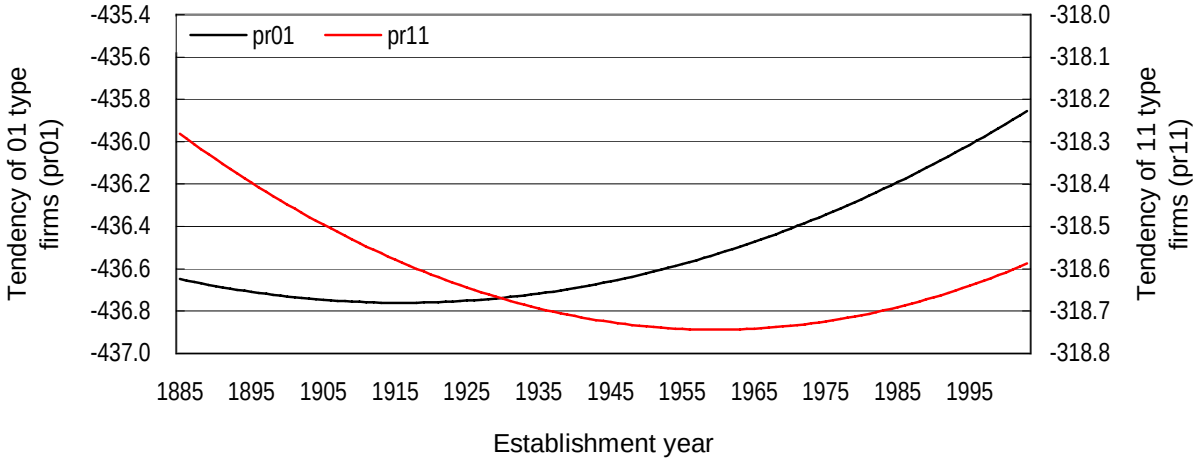


Figure 4c. Relation of Internal R&D ratio and firm type

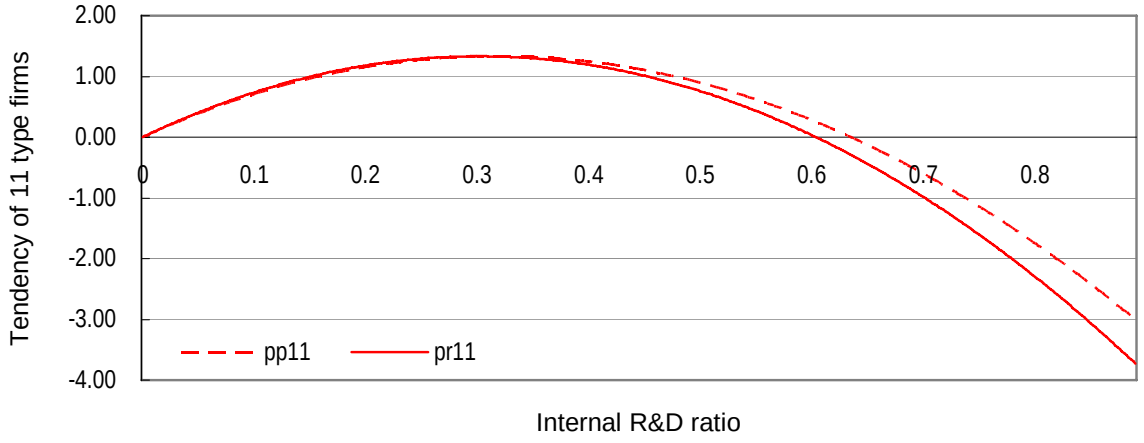


Table 3. Determinants of R&D outsourcing intensity

Dependent variable	External R&D ratio per sales							
Sample ranges	10 and 11 type firms				01, 10, and 11 type firms			
Esitimation methods	Tobit model (nt1)		Panel tobit (pt1)		Tobit model (nt2)		Panel tobit (pt2)	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Firm_size	1.8E-06	7E-08 ***	1.8E-06	2E-07 ***	2.0E-06	7E-08 ***	1.8E-06	7E-08 ***
Firm_size (sq)	-3.0E-11	1E-12 ***	-2.3E-11	3E-12 ***	-3.2E-11	2E-12 ***	-2.9E-11	1E-12 ***
Establishment year	-0.006	1E-03 ***	-0.007	1E-03 ***	-0.009	1E-03 ***	-0.009	9E-04 ***
Establishment year (sq)	1.7E-06	3E-07 ***	1.8E-06	4E-07 ***	2.4E-06	3E-07 ***	2.3E-06	2E-07 ***
Internal R&D ratio	0.162	0.005 ***	0.098	0.006 ***	0.110	0.005 ***	0.101	0.005 ***
Internal R&D ratio (sq)	-0.176	0.015 ***	-0.109	0.017 ***	-0.078	0.015 ***	-0.068	0.014 ***
Pharmaceuticals	0.014	0.001 ***	0.014	0.001 ***	0.015	0.001 ***	0.014	0.001 ***
Telecommunication	0.005	0.001 ***	0.004	0.001 ***	0.005	0.001 ***	0.004	0.001 ***
Precision machinery	0.004	0.001 ***	0.004	0.001 ***	0.004	0.001 ***	0.004	0.001 ***
Chemical	0.004	0.000 ***	0.003	0.001 ***	0.004	0.000 ***	0.004	0.000 ***
Electrical	0.002	0.000 ***	0.001	0.001 *	0.002	0.000 ***	0.002	0.000 ***
Electronics	0.002	0.001 ***	0.001	0.001	0.003	0.001 ***	0.002	0.000 ***
Rubber	0.000	0.001	0.003	-	0.000	0.001	0.000	0.001
Transportation	0.001	0.000	-0.001	0.001	0.001	0.000	0.000	0.000
Oil & coal	0.007	0.001 ***	0.003	0.002 **	0.009	0.001 ***	0.008	0.001 ***
Nonferrous metal	0.006	0.001 ***	0.003	0.001 ***	0.006	0.001 ***	0.005	0.001 ***
Plastics	0.000	0.001	-0.002	0.001 *	0.000	0.001	0.000	0.001
Textile & clothing	0.003	0.001 ***	0.001	0.001	0.003	0.001 ***	0.003	0.001 ***
Ceramics	0.001	0.001 *	0.001	0.001	0.001	0.001 **	0.001	0.001 **
Tan & fur	0.007	0.002 ***	-0.017	-	0.006	0.002 ***	0.005	0.002 ***
Metal	0.000	0.001	-0.001	0.001	0.000	0.001	0.000	0.000
Furniture	0.005	0.001 ***	0.004	0.001 ***	0.005	0.001 ***	0.004	0.001 ***
Drink & tobacco	0.003	0.001 ***	0.001	0.001	0.002	0.001 *	0.001	0.001
Iron & steel	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001
Food	-0.001	0.000 **	-0.003	0.001 ***	-0.002	0.000 ***	-0.002	0.000 ***
Paper & pulp	-0.002	0.001 **	-0.005	0.002 ***	-0.002	0.001 ***	-0.002	0.001 ***
Print	-0.002	0.001 **	-0.004	0.002 *	0.000	0.001	0.000	0.001
Wood	-0.006	0.002 ***	-0.005	0.003 *	-0.006	0.002 ***	-0.005	0.002 ***
Others	0.003	0.001 ***	0.002	0.001	0.004	0.001 ***	0.004	0.001 ***
Time trend	0.000	0.000 *	0.000	0.000 **	0.000	0.000 *	0.000	0.000 *
Number of obs	57737		57737		59140		59140	
Log likelihood	13315		19160		14792		15492	

Notes: Base industry is general machinery. Statistical significance; * 10%, ** 5%, *** 1%

Figure 5a. Relation of firm size and external R&D ratio

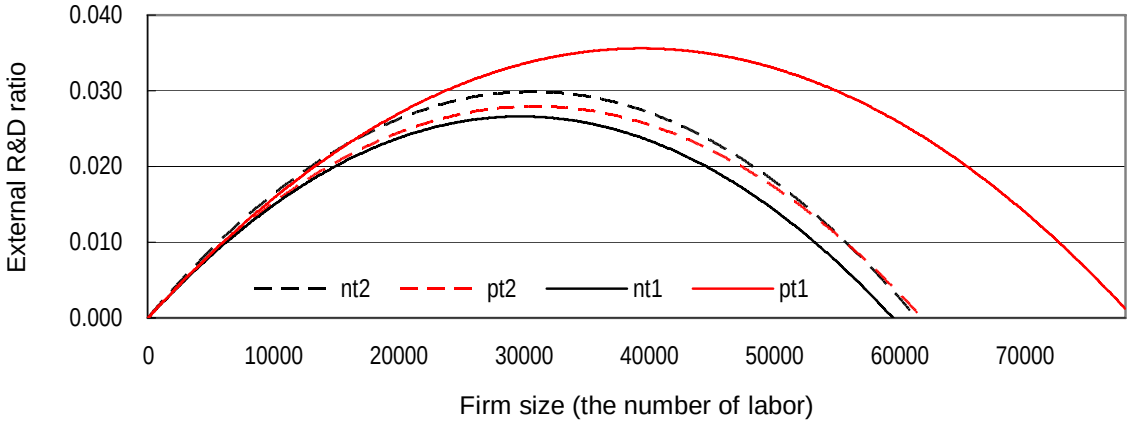


Figure 5b. Relation of Establishment year and External R&D ratio

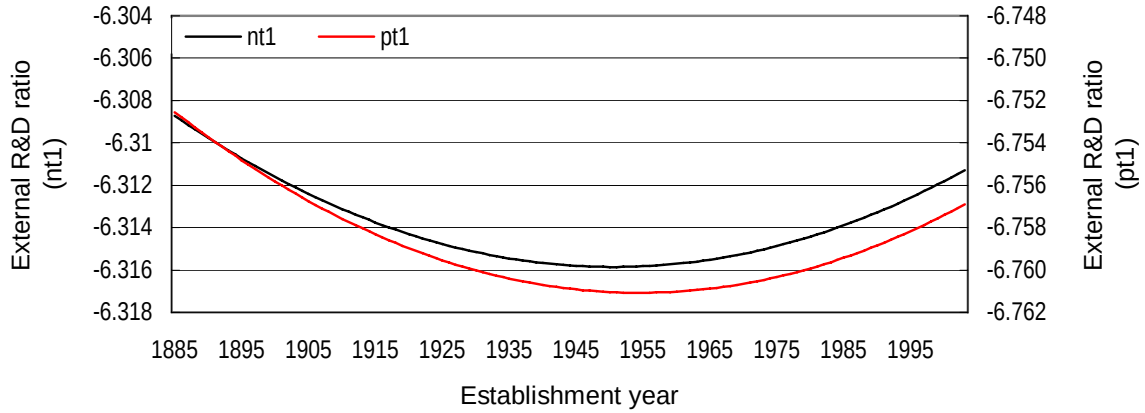
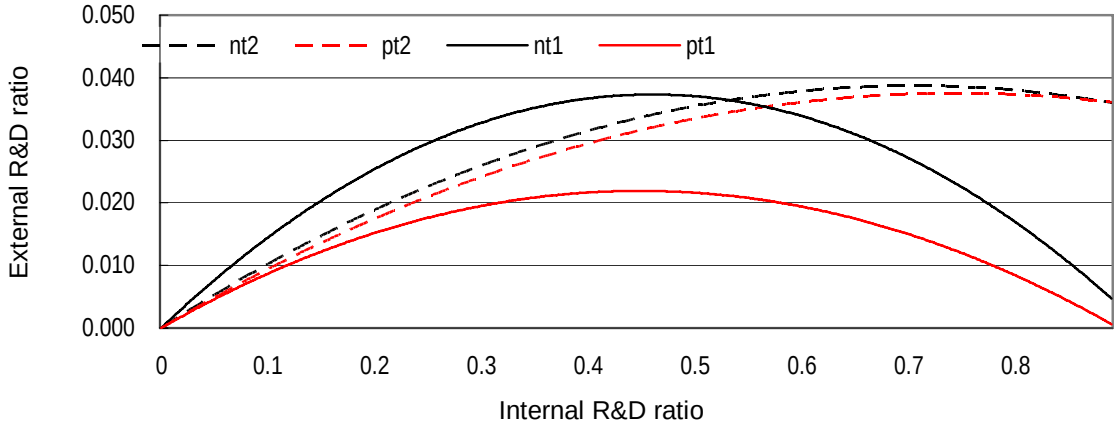


Figure 5c. Relation of Internal and External R&D ratio



3.2. Determinants of External R&D Utilization

The analysis so far has examined whether companies choose to engage in external R&D. The following empirical exercise augments it by investigating the factors that influence the degree of R&D outsourcing. The dependent variable is external R&D/sales ratio. As the ratio is censored at zero, the tobit model is used to estimate its relationship with the same set of explanatory variables adopted in the previous analysis.

Regression results are presented in Table 3. The left panel (nt1 and pt1) uses observations from category 01/11 firms, and the right panel (nt2 and pt2) employs all samples from three R&D location category 01/10/11. The "nt" models pool observations, while the "pt" models use the random effects specifications. Findings from these models are basically the same as the ones from probit estimates in Table 2. The firm size estimates support earlier results that large firms tend to utilize external R&D to a greater extent. Similarly, the coefficients of establishment year variables suggest that the young firms not only choose to conduct R&D outsourcing, but also exploit it to a greater extent. These results also reveal that, as internal R&D ratio rises, external R&D ratio increases at a diminishing rate. The mutually enforcing relationship between internal and external R&D is consistent with the learning role of internal R&D. The relationship of these three factors with external R&D ratio is shown in Figures 5a-5c. On the industry level, it is R&D intensive industries that use external R&D to a greater degree. Five most R&D intensive industries are all characterized with the tendency to complement internal R&D with inventive outsourcing.

4. Concluding Remarks

This paper has examined firm's external R&D from two perspectives. One is whether companies engage in R&D outsourcing, and the other is the extent to which they make use of outside resources. These two analyses yield almost identical results. Internal R&D activities are found to facilitate external R&D, which implies that R&D activities conducted inside and outside of firms do not replace each other. Instead, they are complements, which is consistent with the view that internal R&D nurtures firm ability to better evaluate external R&D partners and to assimilate R&D fruits available externally.

Another finding is that it is relatively large firms that resort to external R&D utilization. Firms that are on the both ends of age range also exploit external R&D. That the relatively young, fledgling companies tend to rely on external R&D has public

policy implications. If they need to depend on outside inventive resources during the early phase of operation, government agencies responsible for promotion of corporate start-ups should design policies to facilitate markets for inventive resources. This would include exchange of information on corporate R&D expertise. In order to gain a better insight into this issue, more detailed studies into the category 01 firms would be worthwhile.

Notes:

1 Although firms may alternatively choose to collaborate with others by conducting joint R&D projects, this paper concentrates on a firm's choice between internal and external R&D activities.

2 A counter evidence is presented in Cohen, Levin and Mowery (1987), which find that overall firm size has a very small, statistically-insignificant effect on business unit R&D intensity when either fixed industry effects or measured industry characteristics are taken into account. They also find that business unit size has no effect on the R&D intensity of business units that perform R&D, but it affects the probability of conducting R&D.

3 The data source is *Report on the Survey of Research and Development* (various years) prepared by Statistics Bureau, Ministry of Internal Affairs and Communications, Government of Japan. The documents report corporate R&D expenditures disbursed to finance internal as well as external R&D that are aggregated by industry. The share in Figure 1 is calculated as percentage share of external R&D in the total (internal and external) disbursements.

4 Matsuura and Kiyota (2004) provide a detailed description of the survey data. Examples of studies using the METI survey data to investigate corporate behavior include Fukao, Ito and Kwon (2005) that engaged in a comparative study of foreign-owned and domestically-owned firms.

5 The probit analyses reported here are conducted separately for category 01 and 11 firms with category 10 firms as the baseline case for each estimate. We also examined the locational issue with category 01/10/11 firm data in the multilogit framework, and obtained results that are broadly similar.

6 Specifically, one could hypothesize that young companies rely on outside resources to engage in R&D before their own inventive capacities are established. After a firm establishes itself, managers may regard innovation as a source of further expansion.

7 This relationship is eventually reversed for firms with more than 30,000 employees. As the sample mean employee is 625 (with standard deviation of 2533), however, this negative relationship holds for most firms. See Appendices Table A2 for summary statistics.

8 The internal R&D variables are omitted from pr01 and pp01 regressions, as they are not compatible with identification of attributes of category 01 firms.

9 The pooling and random effect model regressions of internal R&D expenditure on the number of employee (using the same observations) produce the positive and significant coefficients.

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Appendices:

Table A1. Total R&D Ratio by Industry and Breakdown by R&D Location Category

Industry	Total R&D Ratio	Obs.	Category		
			01	10	11
Pharmaceutical	0.064	1981	14	1009	958
Telecommunication	0.036	1557	31	1173	353
Precision machinery	0.034	2160	39	1680	441
Chemical	0.033	5813	63	4296	1454
Electrical	0.029	5596	124	4549	923
Electronics	0.026	3452	99	2731	622
General machinery	0.021	8924	172	7630	1122
Rubber	0.020	853	16	733	104
Transportation	0.017	5115	106	4186	823
Oil & coal	0.014	350	46	215	89
Nonferrous metal	0.014	1514	63	1138	313
Plastic	0.014	3127	75	2691	361
Textile	0.013	1623	61	1340	222
Ceramics	0.013	2593	69	2198	326
Tan & fur	0.011	210	5	164	41
Metal	0.010	4353	110	3764	479
Furniture	0.009	889	35	698	156
Drink & tobacco	0.009	1156	17	956	183
Iron & steel	0.008	1343	71	1081	191
Food	0.008	6005	116	5326	563
Paper & pulp	0.008	1238	30	1108	100
Print	0.008	925	48	801	76
Clothing	0.007	794	39	659	96
Wood	0.003	369	10	343	16
(Other industries)	0.019	1421	55	1160	206
TOTAL	0.020	63361	1514	51629	10218

Note: Total R&D Ratio is derived by dividing the sum of internal and external R&D by s

Table A2. Statistic summary

Variables	Obs	Mean	Std. Dev.	Min	Max
External R&D ratio	63361	0.001	0.006	0	0.500
01type firm dummy	63361	0.024	0.153	0	1
11type firm dummy	63361	0.161	0.368	0	1
Firm size	59141	625	2533	0	77183
Establishment year	63359	1958	15.88	1885	2003
Internal R&D ratio	63361	0.019	0.028	0	0.887

Notes: n = 59140 for correlation coefficients