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Determinants of R&D Activities by Start-up Firms: Evidence from Japan

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Summary

The start-up of new businesses has been attracting considerable attention due to their potential contribution to innovation. However, there are few econometric studies on the determinants of R&D by start-up firms. Using firm-level, industry-level, and regional data, this paper examines the determinants of R&D investment by Japanese start-up firms in the manufacturing sector. Specifically, this study employs probit analysis on the probability of R&D investment and Tobit analysis on R&D intensity. Empirical results demonstrate that firm size and appropriability have significant positive impacts on both the probability of R&D investment and R&D intensity, while technological opportunity and the regional agglomeration of research institutes and human resources have significant positive effects on R&D intensity. These findings highlight the importance of regional intellectual infrastructure in promoting R&D of start-up firms.

Keywords: Start-up Firm; Small and Medium Enterprise (SME); R&D; Japan

1. Introduction

The start-up of new businesses has been attracting considerable attention due to their potential contribution to innovation. This also applies to Japan, where the policy for small and medium enterprises (SMEs) recently underwent a substantial change from the general protection of SMEs to the targeted support of new and innovative firms.

The small and medium enterprises (SMEs) in Japan, which have been regarded as weak, suppressed, and low-tech firms and thus, as targets of protective policies, have recently started to attract considerable attention as promoters of innovation (Small and Medium Enterprise Agency (ed.), 2002). Particular attention is paid to start-up firms including new ventures that enter the markets with new products and services based on new technologies and ideas or exploit new markets. Although large, mature firms also play an important role in innovation, the contribution of small, new firms cannot be ignored (Acs and Audretsch, 2003).

Table 1 summarizes the R&D activities of Japanese firms by employee size classes, based on recent official statistics. Remarkable differences in the ratio of firms conducting R&D can be observed between the firm-size classes. This ratio is considerably higher in large firms

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(with more than 300 employees) than in SMEs (with less than 300 employees). However, if we focus on the firms that conducted R&D, the differences between the large firms and SMEs mostly disappear with regard to both the ratio of research personnel to the total employees and the ratio of R&D expenditure to sales. Considering an average of all the sectors, large firms and SMEs have similar R&D/sales ratios[1].

However, due to the lack of available data, we have very limited knowledge about the R&D activities of start-up firms. Table 2 presents some information about the R&D input of firms that were established during the period 1994–1999, based on the data from "the Survey on Start-up Firms" conducted by the Japan Small Business Research Institute (JSBRI) in 2002 (Ito and Akashi, 2005)[2]. Approximately 60% of the firms in the entire sample (and 52% in the manufacturing sector) conducted R&D either continuously or occasionally since their establishment. The average R&D intensity (the ratio of R&D expenditure to sales) is 7% for the entire sample and 11% for the manufacturers, if we focus on the firms that reported the values of R&D expenditure. Although this evidence is based on survey data with a limited number of observations, which renders a direct comparison with the data in Table 1 difficult, we can at least assume that the R&D intensity of the start-up firms conducting R&D is higher than that of SMEs collectively.

The data in Table 2 indicate large disparities in R&D activities among start-up firms. However, no in-depth studies have been carried out with regard to the determinants of R&D conducted by start-up firms. Previous studies concentrate on large, mature firms; however, considering the increased expectations of start-up firms as the promoters of innovation, it is important to examine the factors that promote R&D by start-up firms.

From the viewpoint of social welfare, a high level of R&D investment is not always desirable because the R&D investment may exceed the social optimum, and R&D may not necessarily be conducted efficiently[3]. However, for SMEs and especially for start-up firms, the level of R&D investment tends to be lower than the social optimum because of the high risk that accompanies R&D.

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[1] The SMEs often conduct informal R&D, which is not shown in terms of expenditure and number of personnel. Therefore, the R&D activities of SMEs are likely to be underestimated in the statistics (Kleinknecht, 1987; Santarelli and Sterlacchini, 1990; Kleinknecht and Reijnen, 1991).

[2] This questionnaire survey was carried out in 2002 for 10,000 start-up firms (random sampling) in the manufacturing, wholesale, retail, transportation, telecommunication, restaurant, and service sectors that were established during the period 1994–1999. Answers were obtained from 11% of the firms.

[3] The argument that R&D investment is likely to be lower than the social optimum is grounded in the problems of externalities (spillover effect) and the high risk involved in R&D. On the contrary, if the R&D competition between the firms is characterized by a "rank-order tournament," in which the first inventor can appropriate the returns from the innovation, a "rush to invent" is likely to occur. Such a situation leads to a socially excessive R&D competition in order to be the first inventor, and the R&D investment of the losers constitutes a social loss (Barzel, 1968).

Thus, using firm-level, industry-level, and regional data, this paper analyzes the determinants of R&D activities of start-up firms in Japan[4]. Compared to previous studies, this paper is characterized by its focus on start-up firms and regional factors.

The remainder of this paper is organized as follows. Section 2 provides a brief review of previous studies on the determinants of R&D. In Section 3, we explain the method, hypotheses, and data for the empirical analysis. Section 4 presents the estimation results and a discussion about the results. Section 5 presents some concluding remarks.

2. Determinants of R&D Investment: A Review of Previous Studies

Previous studies on the determinants of R&D from an economic perspective can be classified into two types. The first type focuses on the effects of firm size and market structure as well as industry-specific characteristics of technology, based on the Schumpeterian Hypothesis. The second type focuses on firm-specific factors other than firm size, with a special emphasis on financial constraints.

Previous empirical studies on the relationship between firm size and R&D do not sufficiently support the Schumpeterian Hypothesis (Cohen and Levin, 1989; Cohen, 1995). Recent studies argue that industry-specific factors such as the appropriability of innovative outcomes and technological opportunity are more essential in determining R&D than firm size. Here, the appropriability refers to the extent to which the innovator can secure private returns from an innovation against spillover and imitation, and it depends on legal and private measures of protection. Technological opportunity indicates the richness of the chances of innovation and the ease of achieving the goals of innovation, and it depends on the development of related sciences and the availability of useful external information. Another important industry-specific factor is the demand factor (the current level and growth of demand). Since R&D is expected to be more intensive, the higher the demand and the profit expected from innovation.

Recent studies pay particular attention to firm-specific factors other than firm size, with a special emphasis on the financial factor[5]. If the capital market is perfect and there is no information asymmetry between the investors and the recipients of capital, there will be no differences in capital cost between internal and external funds. However, in reality, the capital market is imperfect, and the asymmetry of information increases the cost of external funding because of the monitoring cost and risk premium. Thus, R&D investment, which is

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[4] There is no consensus with regard to the duration of the "start-up" period. An appropriate course would be to limit the period to within a maximum of 10 years of establishment. In this paper, however, we regard start-up firms as those that have been established since less than 15 years, due to the availability of data. See Footnote 12 for more detail.

[5] Cf. Hall (2002) for a recent survey of studies on the issues of R&D funding.

essentially accompanied by high risk, is constrained by the availability of internal funds. Therefore, firms with relatively abundant internal funds are expected to invest more in R&D.

In particular, SMEs have a very limited possibility of obtaining direct finance from the capital market, and their funds are restricted to self-finance and bank loans. However, financing by means of bank loans is not an optimal source of R&D investment because of the risk-averse character of bank loans. Therefore, R&D investment by SMEs strongly depends on the availability of internal funds[6]. Moreover, such a financial constraint is particularly crucial for start-up firms because they are characterized by scarce information and high risk.

Few empirical studies on the determinants of R&D have been carried out in Japan. Doi (1993) finds an over-proportional relationship between firm size and R&D expenditure for large firms. Goto et al. (2002) generate the variables of appropriability and technological opportunity from original survey data and demonstrate that these industry-specific characteristics as well as internal funds are important determinants of the R&D investment of listed manufacturing companies. Using large-scale micro data from official statistics, Kwon and Inui (2003) show that in addition to the above-mentioned factors, capital relationship and information network promote the R&D investment of both large and small firms. Using a dataset of 10,000 manufacturing SMEs, Okamuro (2004) finds that the CEO's educational background and the governance structure represented by the number of shareholders and the type of the largest creditor affect R&D activities[7].

Thus far, Lynskey (2004) is the only study on the determinants of innovation by Japanese start-up firms. Using the number of patent applications and new products as measures of innovation output, he demonstrates that certain firm-specific factors (technological capability, availability of internal funds, venture capital funding, and university-industry linkages) and managerial factors (the CEO's educational background and capacity for networking) are important determinants of innovation.

Thus, previous studies in both Western countries and Japan concentrate on firm- and industry-specific characteristics (and partly on managerial characteristics). On the other hand, some recent studies pay attention to the effects of regional factors such as urbanization and agglomeration. According to the urban hierarchy hypothesis, urban agglomeration is favorable for the firms conducting R&D because of the easy recruitment of a qualified labor force, high information intensity, and proximity to centers of knowledge such as universities, public research institutes, and customers. Therefore, firms are expected to conduct R&D more actively in urban or high agglomeration regions than in rural or low agglomeration regions (Roper, 2001). An argument contrary to this is that inter-firm technology spillover is promoted in high agglomeration regions, which lowers the incentive for R&D because of the

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[6] Acs and Isberg (1991) and Himmelberg and Petersen (1994) demonstrate that the R&D investment of SMEs in research-intensive industries is significantly affected by the availability of cash flow.

[7] Other studies on the impact of the governance structure on R&D investment (Hall and Weinstein, 1996; Wahal and McConnel, 2000; Hosono et al., 2004) target large firms listed on the stock market.

appropriability problem (Bagella and Becchetti, 2002). Several studies on the effects of regional factors have been carried out using data from European countries (Roper, 2001; Bagella and Becchetti, 2002; Smith et al., 2002; Beaudry and Breschi, 2003); however, no evidence supporting the urban hierarchy hypothesis was found.

Jaffe (1989) and Anselin (1997) conducted a more direct examination of the effect of university research on private R&D. They demonstrate that university research has a strong positive impact on regional innovation output, both directly and indirectly, by inducing private R&D investment.

As discussed above, empirical studies on the determinants of R&D began with the examination of the Schumpeterian Hypothesis and an analysis of the effects of financial constraints; they were recently extended to the research of the impacts of the governance structure and regional factors. However, previous studies—particularly those on the effects of firm- and industry-specific characteristics—focused on mature, large firms, and mostly neglected SMEs and start-up firms. Thus, this paper focuses on Japanese start-up firms in the manufacturing sector and analyzes the determinants of R&D investment, considering not only firm- and industry-specific characteristics but also regional factors.

3. Models, Hypotheses, and Data

3.1 Models and Hypotheses

The basic model of this paper is presented as follows:

R&D Activity = f (Firm Characteristics, Industry Characteristics, and Regional Characteristics).

This model indicates that the R&D activity of start-up firms depends on firm, industry, and regional characteristics. R&D expenditure dummy (RDD) and R&D intensity (RDRATIO) are the dependent variables. The former is a dummy variable that takes on the value of one if the firm has a positive R&D expenditure and zero otherwise. The latter is the ratio of R&D expenditure to sales. We employ a probit model to estimate the probability of positive R&D expenditure (RDD) and a Tobit model to estimate R&D intensity (RDRATIO). The Tobit model is used in the latter case because 23% of our sample firms show no R&D expenditure, and thus, their R&D intensity is zero. We estimate both probit and Tobit models in order to examine if the determinants of *whether* to invest in R&D or not are different from those of *how much* to invest in R&D.

Firm characteristics are represented by firm size (SIZE), firm age (AGE), educational background of the CEO (UNIV), and availability of internal funds (CF). Industry characteristics are appropriability (APPRO), technological opportunity (TECHO), and demand growth (GROW). The variables of regional factors are the agglomeration of research institutes (INST) and human resources (PROFF) in each prefecture. The definitions of these variables are summarized in Table 3 and discussed in detail later.

Using these variables, the estimation models are specified as follows. As the regional variables INST and PROFF are expectedly highly correlated, we use them alternatively. Therefore, we estimate four models, two for each dependent variable. In these models, α_0 - δ_0 and ε_1 - ε_4 denote constant and error terms, respectively.

Model 1 (probit analysis):

$$RDD = \alpha_0 + \alpha_1 SIZE + \alpha_2 AGE + \alpha_3 UNIV + \alpha_4 CF + \alpha_5 APPRO + \alpha_6 TECHO + \alpha_7 GROW + \alpha_8 INST + \varepsilon_1$$

Model 2 (probit analysis):

$$RDD = \beta_0 + \beta_1 SIZE + \beta_2 AGE + \beta_3 UNIV + \beta_4 CF + \beta_5 APPRO + \beta_6 TECHO + \beta_7 GROW + \beta_8 PROFF + \varepsilon_2$$

Model 3 (Tobit analysis):

$$RDRATIO = \gamma_0 + \gamma_1 SIZE + \gamma_2 AGE + \gamma_3 UNIV + \gamma_4 CF + \gamma_5 APPRO + \gamma_6 TECHO + \gamma_7 GROW + \gamma_8 INST + \varepsilon_3$$

Model 4 (Tobit analysis):

$$RDRATIO = \delta_0 + \delta_1 SIZE + \delta_2 AGE + \delta_3 UNIV + \delta_4 CF + \delta_5 APPRO + \delta_6 TECHO + \delta_7 GROW + \delta_8 PROFF + \varepsilon_4$$

Firm size (SIZE) is measured by a logarithm of the number of employees. Based on the Schumpeterian Hypothesis and statistical evidence from Table 1, it is expected that both the probability of R&D expenditure and R&D intensity increase with firm size.[8] Considering the reverse causality that the firms that achieved successful innovation increase in size, we use the number of employees in the previous year to allow a lag of one year.

Firm age (AGE) indicates the number of years since the incorporation. The years since establishment are not considered because of numerous missing values. This variable is used as a control variable.

The educational background of the CEO (UNIV), a dummy variable taking on the value of one if the CEO is a university graduate and zero otherwise, is used as a proxy for the orientation toward and the capability of innovation of the top managers. Scherer and Huh

[8] As mentioned earlier, previous empirical results on the Schumpeterian Hypothesis do not necessarily support our hypothesis. However, empirical evidence also shows that R&D intensity tends to increase with firm size to a certain extent. The data in Table 1 also supports this tendency. Therefore, we assume that, the larger the firm size, the more actively SMEs conduct R&D.

(1992) demonstrate that the R&D intensity of firms depends on the fields the CEO studied[9]. However, here, we expect that the R&D activities of start-up firms depend on whether the CEO is a university graduate, because the available data are restricted to the name of the universities that the CEOs graduated from. No information is available with regard to the faculties or the departments at which the CEO studied. Moreover, if a CEO is not a university graduate, no further information is available. Therefore, our data source has many missing values with regard to the educational background of the CEOs. Here, we consider the missing values as indicating that the CEO is not a university graduate, and UNIV takes on the value of zero.

As a proxy for the availability of internal funds, we use the ratio of cash flow (net profit after tax plus depreciation) to sales (CF). Based on the above discussion on financial constraints, we expect that the availability of internal funds has a positive impact on R&D investment. Here again, we use the data of the previous year to cope with the possibility of reverse causality. Moreover, as this variable has many outliers, the observations that are either higher than 1 or lower than –1 are excluded from the analysis.

We use three variables for industry-specific factors: the appropriability of innovative outcomes (APPRO), technological opportunity (TECHO), and the growth of industry demand (GROW). As discussed earlier, we expect that R&D tend to be conducted more actively, the more likely the innovative outcome to be appropriated by the innovator, the better the technological opportunity, and the larger the expected demand growth from innovation.

Among these industry-specific variables, APPRO and TECHO were calculated from the industry-level data of NISTEP (2004), as described later in greater detail. Here, the appropriability represents the extent to which several measures such as patents and business secrets were useful in securing private returns from innovation on the whole. Technological opportunity is measured as the extent to which the firms could obtain useful ideas for innovation from external organizations such as customers and universities.

Demand growth (GROW) measures the changes in the value of shipments at the industry level in the period 1999–2001. Goto et al. (2002) use the latest sales of firms as the variable of expected demand. However, the expected demand growth of start-up firms from innovation would be different from that of large, mature firms, which are better represented by the market size than their current sales. Start-up firms can increase their sales several fold if their innovation achieves commercial success; however, the increase in sales may depend on the current market demand.

Among regional factors, the number of research institutes in each prefecture (INST) is a measure of the knowledge agglomeration in the region. Another variable is the availability of qualified human capital (PROFF), which is measured by the ratio of the workforce engaged

[9] Romijn and Albaladejo (2002) use the academic degrees of the CEOs in the fields of management and natural sciences as their innovative capability.

in professional and technical occupations to the total workforce[10]. According to the urban hierarchy hypothesis, research institutes tend to be located in urban and high agglomeration regions, where local start-up firms can obtain stimulation and support for R&D through intellectual networks with these institutes. Moreover, the higher the ratio of the people engaged in professional and technical occupations in the region, the easier it will be to recruit human resources that support R&D by start-up firms. Therefore, we expect a positive relationship between these regional factors and the R&D activities of start-up firms.

In summation, we present the following hypotheses on the determinants of R&D activities by start-up firms. We regard firm age (AGE) as a control variable, and therefore, no hypothesis is related to this variable. The variables in parentheses correspond to each hypothesis. According to these hypotheses, we expect that the coefficients of all the independent variables have positive signs.

H1: Firm size has a positive impact on the R&D activities of start-up firms (SIZE +).
H2: The CEO's higher education has a positive impact on the R&D activities of start-up firms (UNIV +).
H3: The availability of internal funds has a positive impact on the R&D activities of start-up firms (CF +).
H4: Start-up firms conduct R&D more actively, the higher the level of appropriability of innovative outcomes in the industry they belong to (APPRO +).
H5: Start-up firms conduct R&D more actively, the better the technological opportunity in the industry they belong to (TECHO +).
H6: Start-up firms conduct R&D more actively, the higher the growth rate of shipments in the industry they belong to (GROW +).
H7: The level of regional agglomeration of knowledge and qualified human resources has a positive impact on the R&D activities of start-up firms (INST +, PROFF +).

3.2 Data and Samples

The analysis in this paper uses firm-level, industry-level, and regional data. Firm-level data are obtained from the *JADE database* compiled by Bureau van Dijk in Belgium as of December 2004. Among the industry-specific variables, APPRO and TECHO are generated from the survey data of *National Institute of Science and Technology Policy* (NISTEP, 2004). GROW is calculated from the *1999* and *2001 Census of Manufactures*. Regional data are obtained from the *Regional Economy Database, Version April 2004*, compiled by Toyo

[10] According to the latest Standard Occupation Classification in Japan (as of 1997), professional and technical occupations comprise scientific researchers; various kinds of engineers; medical and health professionals such as doctors and nurses; professionals in social welfare; legal professionals such as lawyers; managerial professionals such as accountants, teachers, artists, etc.

Keizai Inc. However, the original data sources are the *2001 Establishment and Enterprise Census* for the number of research institutes in each prefecture (INST) and the *2000 Population Census* for the ratio of the workforce engaged in professional and technical occupations to total workforce (PROFF).

We calculated the values of APPRO from the large-scale survey data of NISTEP regarding the various measures of appropriating private returns from the most important product and process innovations of the Japanese firms (NISTEP, 2004, Table 44 and 45). This index indicates the extent to which the appropriation of innovative outcomes is possible, irrespective of the measures of appropriation. The values of TECHO are calculated from the NISTEP survey data on the various sources of information for new innovation projects (NISTEP, 2004, Table 37). This index indicates how easily useful information for innovation can be accessed, irrespective of the sources of innovation[11].

The JADE database adopts the industry classification system of *Teikoku Data Bank*—a major Japanese credit research company that provides the original data to JADE. On the other hand, APPRO and TECHO are based on the industry classification by NISTEP (2004). Thus, we adjusted these different classifications to the Japanese Standard Industry Classification (JSIC) Version 11, at the 2-digit level. However, industry demand growth (GROW) was calculated according to JSIC Version 10, because we used the data before the revision.

Our sample comprises start-up firms in the Japanese manufacturing sector for which financial data for the fiscal years 2002 and 2003 are available from the JADE database. We defined start-up firms as those that have been established for less than 15 years[12], restricted the sample to SMEs (firms with less than 300 employees), and excluded the missing data and outliers, especially with regard to R&D intensity and cash flow. Thus, our final sample comprises 92 firms. The small size of our sample is mainly because start-up firms occupy a minor position in the JADE database.

Almost 30% of the sample firms are concentrated in the electrical machinery industry. Firms in the electrical machinery and food industries together constitute the majority of the sample. Compared to the industry composition of the manufacturing SMEs that were established between 1985 and 1999, which was calculated from the *1999 Establishment and Enterprise Census*, our sample firms are characterized by an over-proportional presence of

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[11]This method of generating the variables of appropriability and technological opportunity based on the NISTEP survey data is employed in Goto et al. (2002), Kwon and Inui (2003), and Okamuro (2004) as well.

[12] As discussed earlier, there is no general consensus on the duration of the start-up period. Based on an analysis using micro data from the Census of Manufactures, Small and Medium Enterprise Agency (ed.) (2002) states that "finally, in 10 and some more years since establishment, the differences (in average firm size and productivity) between the new and the existing establishments almost disappear: Newly founded SMEs attain maturity" (p. 72) (supplements by the author in parentheses). As Sakakibara et al. (2004) consider firms that have been established for less than 10 years as start-up firms, it may be generally accepted that the start-up period should be limited to within 10 years of establishment. However, in this paper, the firms that have been established for less than 15 years are regarded as start-up firms in order to obtain a sufficient sample size for the empirical analysis. This is because the JADE database does not contain many firms established for less than 10 years.

the electrical machinery and food industries. With regard to the geographic distribution, our sample firms are located in 26 of the 47 prefectures; the majority of them are located in the four urban prefectures of Tokyo, Osaka, Aichi, and Kanagawa, with Tokyo accounting for about a quarter of all establishments. Compared to the geographic composition of the manufacturing establishments with more than 4 employees obtained from the *2001 Census of Manufactures*, our sample firms show a remarkably high concentration of these firms in the metropolitan regions, especially in Tokyo. Thus, our sample firms do not entirely represent the start-up firms, at least with regard to industrial and geographic composition. Therefore, we should be aware of the potential influence of such a sampling bias on the estimation results while interpreting them.

Table 4 presents the basic statistics of this sample. As mentioned earlier, we excluded the missing values for all the variables except the educational background of the CEO (UNIV), in which case we consider that all the missing values take on the value of zero (i.e., the CEO is not a university graduate). If the missing values included university graduates, the values of UNIV would be underestimated. Moreover, we excluded some outliers with regard to the variables RDRATIO and CF.

In 2003, 73% of the firms reported R&D expenditure, with positive values in most cases. The R&D intensity was 1.6% on an average, which was remarkably higher than that of all the manufacturing SMEs in the database (0.9%). On an average, sample firms had 29 employees and survived for 12 years. The average cash flow/sales ratio was 1.8%. Sixty percent of the firms reported the name of the university attended by the CEO.

4. Empirical Results and Discussion

The results of the empirical analysis are presented in Table 5. Models 1 and 2 show the results of the probit analyses on the probability of conducting R&D (RDD). Models 3 and 4 show the results of the Tobit analyses on R&D intensity (RDRATIO). Models 1 and 3 include INST as the regional factor, while Models 2 and 4 include PROFF as the regional factor. These variables are used interchangeably because of the high correlation between them.

With regard to the probability of conducting R&D (RDD), only SIZE and APPRO have positive and significant coefficients, as expected. The other variables have no significant effects. Thus, firm size and the appropriability of innovative outcomes have positive impacts on the probability of conducting R&D; however, firm age, the educational background of the CEO, availability of internal funds, technological opportunity, demand growth of the industry, and regional factors do not have significant effects. These results support Hypotheses 1 and 4.

With regard to R&D intensity (RDRATIO), SIZE, APPRO, TECHO, INST, and PROFF have positive and significant coefficients, as expected. However, other variables—AGE, UNIV, CF, and GROW—do not have significant effects. Thus, firm size, appropriability, technological opportunity as well as the regional agglomeration of knowledge and qualified human resources have positive impacts on R&D intensity; however, firm age, the educational background of the CEO, availability of internal funds, and the demand growth of the industry have no significant effects. These results support Hypotheses 1, 4, 5, and 7.

The estimation results suggest that the determinants of conducting R&D and those of R&D intensity are partially different. In particular, the technological opportunity of the industry and the regional agglomeration of knowledge and human capital have significant effects on the R&D intensity of start-up firms, but not on whether they conduct R&D.

The findings that neither the educational background of the CEO nor the availability of internal funds affects the R&D activities of start-up firms are surprising because we expect that the activities of start-up firms depend more heavily on the ability of the CEO and financial constraints than do those of mature, large firms.

Our estimation results are partially consistent with those of the previous studies. With regard to the effects of firm size and the technological characteristics of the industry in particular, we obtained results similar to those of major previous studies. The results with regard to regional factors support the urban hierarchy hypothesis; however, they are not consistent with the results of the previous studies that reject this hypothesis in general. This paper does not use the same variables of the regional factors as in the previous studies, and therefore, it is difficult to compare the results directly. However, since most previous studies do not focus on start-up firms, our results suggest that the regional agglomeration of knowledge and human resources is of particular importance in increasing the R&D intensity of start-up firms.

5. Conclusion

In this paper, we analyzed the determinants of R&D activity by start-up firms in the manufacturing sector in Japan by using firm-level, industry-level, and regional data. Innovation by start-up firms has recently attracted considerable attention; however, previous studies on the determinants of R&D concentrated on mature, large firms. Very few econometric studies were carried out on the determinants of R&D by SMEs, particularly by start-up firms. Moreover, compared to the firm and industry characteristics, the effects of regional factors have not been sufficiently investigated. Therefore, the major focus of this paper is on SMEs at the start-up stage and on regional factors as the determinants of R&D.

Based on major arguments on the determinants of R&D, such as the Schumpeterian Hypothesis, industry-specific technological features, financial constraints due to information asymmetry and the incomplete capital market, and the urban hierarchy hypothesis in the field of regional studies, we presented the related variables and hypotheses.

The empirical results using data of 92 manufacturing start-up firms demonstrate the following: (1) firm size and the appropriability of innovative outcomes have positive effects on both the probability of conducting R&D and R&D intensity; (2) technological opportunity and the regional agglomeration of knowledge and human resources have positive effects only on R&D intensity; and (3) surprisingly, the educational background of the CEO, the availability of internal funds, and the industry growth rate have no significant impacts on R&D activity.

These results support several hypotheses in this paper. Specifically, there are two important findings. The first is that the technological features of the industry, namely appropriability and technological opportunity, are essential factors that enhance the incentives of R&D not only for mature, large firms but also for small, start-up firms. The second important finding is that the R&D intensity of start-up firms is significantly influenced by the regional agglomeration of knowledge and human resources. From these findings, we may derive a policy implication that given the industry characteristics, it is essential to promote the formation of knowledge clusters and of qualified human resources in the region in order to support the R&D activities of local start-up firms.

However, some caution is necessary when arriving at general conclusions and implications from our findings. The first limitation of this study is the size and the possible bias of the sample. As mentioned earlier, the database we used comprises a relatively small number of start-up firms and numerous missing values; therefore, we could not insist on obtaining a sufficient sample size. Moreover, our sample firms show a higher concentration in the electrical machinery industry and in the Tokyo Metropolitan Prefecture as compared to the entire distribution of the firms and establishments in the official statistics. Therefore, we should avoid any simple generalizations based on our results.

Another problem is informal R&D. SMEs are characterized by informal R&D that cannot be measured by the value of R&D investments or the number of research personnel (Kleinknecht, 1987; Santarelli and Sterlacchini, 1990; Kleinknecht and Reijnen, 1991). This paper does not consider informal R&D due to the limitations of the data; however, we should be aware that we are not able to precisely measure and analyze the R&D activities conducted by SMEs, including start-up firms, without considering informal R&D.

Finally, we should be cautious in the interpretation of the impact of regional factors. This paper finds a positive and significant relationship between the variables of the regional agglomeration of knowledge and human resources on one hand and the R&D intensity of the local start-up firms on the other. However, it is not clear *how* they are related concretely. Specifically, our analysis does not provide a direct answer to the question of whether the regional environments stimulate start-up firms to enhance the R&D intensity or attract research-intensive firms to establish themselves there. This issue requires further investigation.

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Table 1: R&D Intensity in Japan by Firm Size Classes (2003)

Firm size classes (number of employees)	Ratio of the firms conducting R&D (%)	Ratio of the research personnel to the total number of employees (%)[2]	Ratio of R&D expenditure to total sales (%)[2]
All sectors[1]	4.6	7.2	2.98
1Š299	4.0	6.4	2.52
300Š999	48.0	4.5	1.84
1,000Š2,999	34.7	7.1	2.15
3,000Š9,999	80.0	8.1	2.91
10,000 and more	92.6	10.4	4.67
Manufacturing	13.0	8.4	3.71
1Š299	11.5	5.6	2.01
300Š999	70.4	4.8	2.22
1,000Š2,999	92.0	8.5	2.73
3,000Š9,999	96.4	11.0	4.21
10,000 and more	100.0	14.4	5.92

Notes:

1) excluding banking and insurance

2) limited to the firms conducting R&D

Source: Ministry of Internal Affairs and Communications, *Report on the Survey of Research and Development 2004.*

Table 2: R&D Activities of Start-up Firms

	Manufacturing	Wholesale	Service	Total [4]	No. of Obs.
Ratio of firms conducting R&D since establishment (%) [1]	51.8	77.1	71.7	59.8	994
Ratio of firms with positive values of R&D expenditure in 2001(%) [2]	86.4	69.6	68.7	71.5	502
Ratio of R&D expenditure to total sales in 2001 (%) [3]	11.0	3.0	7.3	6.9	N.N.

Notes:

1) the ratio of firms that conducted R&D either continuously or occasionally since establishment

2) the ratio of firms that reported positive values of R&D expenditure (to those reporting the values of R&D expenditure in 2001)

3) the average ratio of R&D expenditure to total sales in 2001 (of the firms that reported the values of R&D expenditure)

4) The sample comprises manufacturing, wholesale, retail, transportation, telecommunication, services, and restaurants.

Source: Ito and Akashi (2005)

Table 3: Definitions of the Variables

Variables	Level[1]	Definitions	Year
RDD	firm	R&D dummy (1 if R&D expenditure is positive)	End of 2003
RDRATIO	firm	R&D intensity (R&D expenditure/sales)	End of 2003
SIZE	firm	Number of employees (logarithm)	End of 2002
AGE	firm	Years since incorporation	End of 2002
UNIV	firm	Dummy for the CEO's educational background (1 if the CEO is a university graduate)	the latest investigation
CF	firm	Cash flow ratio[2]	End of 2002
APPRO	industry	Index of appropriability[3]	1999-2001
TECHO	industry	Index of technological opportunity[3]	1999-2001
GROW	industry	Growth rate of industry shipments	1999-2001
INST	region	Number of research institutes in each prefecture	2001
PROFF	region	Ratio of the labor force engaged in professional and technical occupations to the total labor force in each prefecture[3]	2000

Notes:

1) The classification of industries is based on the Japanese Standard Industry Classification.
The unit for regions is prefecture.

2) (net profit after tax + depreciation)/sales

3) See the main text for details.

Table 4: Basic Statistics

Variables	Mean	Median	Std. Dev.	Min.	Max.	No. of Obs.
RDD	0.728	1	0.447	0	1	92
RDRATIO	0.016	0.002	0.035	0	0.173	92
SIZE	3.353	3.384	1.051	0	5.521	92
AGE	11.8	12	2.7	5	15	92
UNIV	0.598	1	0.493	0	1	92
CF	0.018	0.027	0.211	Š0.75	0.601	92
APPRO	1.347	1.258	0.195	0.946	1.696	92
TECHO	0.879	0.861	0.077	0.731	1.057	92
GROW	Š0.124	Š0.099	0.102	Š0.424	0.094	92
INST	343	190	309	25	821	92
PROFF	0.142	0.139	0.021	0.108	0.169	92

Table 5: Estimation Results

	R&D dummy (RDD)		R&D intensity (RDRATIO)	
Variables	Model 1(Probit)	Model 2 (Probit)	Model 3 (Tobit)	Model 4 (Tobit)
Constant	Š4.43 *	Š5.94 **	Š0.280 ***	Š0.355 ***
	(Š1.88)	(Š2.32)	(Š5.50)	(Š6.66)
SIZE	0.366 **	0.368 **	0.0118 ***	0.0112 ***
	(2.40)	(2.40)	(3.13)	(3.00)
AGE	Š0.0107	Š0.00682	0.00136	0.00134
	(Š0.181)	(Š0.115)	(1.00)	(0.992)
UNIV	0.0991	0.127	0.00280	0.00337
	(0.310)	(0.396)	(0.366)	(0.444)
CF	0.358	0.278	Š0.771EŠ03	Š0.00139
	(0.485)	(0.370)	(Š0.0397)	(Š0.0719)
APPRO	1.74 **	1.63 *	0.0636 ***	0.0566 ***
	(2.07)	(1.91)	(3.18)	(2.79)
TECHO	1.52	1.58	0.145 ***	0.146 ***
	(0.686)	(0.704)	(3.14)	(3.18)
GROW	Š0.451	Š0.549	Š0.0180	Š0.0275
	(Š0.301)	(Š0.376)	(Š0.448)	(Š0.702)
INST	0.687EŠ03		0.461EŠ04 ***	
	(1.16)		(3.40)	
PROFF		12.4		0.698 ***
		(1.54)		(3.76)
Log Likelihood	Š46.3	Š45.8	120.0	120.6
Pseudo R-Squared	0.157	0.167		
No. of Obs.	92	92	92	92

Notes: t-values in parentheses. Level of significance: *** 1%, ** 5%, * 10%.

Appendix 1: Industrial Composition of the Sample Firms

Industries [1]	Sample Firms		Entire Population [2]	
	Number	Share	Number	Share
Food	19	0.207	16,197	0.081
Beverages, Tobacco, and Feed	1	0.011	2,250	0.011
Textile	2	0.022	5,402	0.027
Clothing	2	0.022	15,300	0.077
Lumber and Wood Products	0	0.000	4,901	0.025
Furniture and Fixtures	2	0.022	8,412	0.042
Pulp and Paper Products	2	0.022	3,857	0.019
Printing and Publishing	5	0.054	19,910	0.100
Chemical Products	0	0.000	2,835	0.014
Petroleum and Coal Products	0	0.000	393	0.002
Plastic Products	2	0.022	10,464	0.052
Rubber Products	0	0.000	2,656	0.013
Leather Products	0	0.000	2,511	0.013
Ceramic, Stone, and Clay Products	5	0.054	7,526	0.038
Iron and Steel	0	0.000	2,259	0.011
Nonferrous Metals	0	0.000	1,805	0.009
Metal Products	4	0.043	25,786	0.129
General Machinery	14	0.152	26,276	0.131
Electrical Machinery	26	0.283	17,301	0.087
Transportation Equipments	3	0.033	8,574	0.043
Precision Instruments	2	0.022	3,983	0.020
Miscellaneous Industries	3	0.033	11,302	0.057
Total	92	1.000	199,900	1.000

Notes:

1) according to the Standard Industry Classsification for Japan, Version 10

2) Manufacturing establishments founded during 1985Š99 with less than 300 employees (based on the "*1999 Establishments and Enterprise Census* ")

Appendix 2: Regional Composition of the Sample Firms

Prefectures [1]	Sample Firms		Entire Population [2]	
	Number	Share	Number	Share
Tokyo	25	0.342	27,066	0.117
Kanagawa	10	0.137	12,600	0.054
Osaka	6	0.082	29,638	0.128
Aichi	6	0.082	25,994	0.112
Shizuoka	4	0.055	14,630	0.063
Hyogo	3	0.041	13,066	0.056
Saitama	2	0.027	17,483	0.076
Nagano	2	0.027	7,565	0.033
Others	34	0.466	168,225	0.727
Total	92	1.000	316,267	1.000

Notes:

1) Prefectures are ordered according to the number of the sample firms

2) Number of manufacturing establishments with 4 or more employees (based on the "*2001 Census of Manufactures* ").

Appendix 3: Industry Characteristics (Appropriability, Technological Opportunity, and Demand Growth)

Industries [1]	Appropriability [2]	Technological Opportunity [2]	Demand Growth [3]
Food	1.175	0.861	Š0.041
Beverages, Tobacco, and Feed	1.175	0.861	Š0.009
Textile	1.501	0.770	Š0.234
Clothing	0.946	0.761	Š0.320
Lumber and Wood Products	1.588	0.731	Š0.201
Furniture and Fixtures	1.258	0.731	Š0.197
Pulp and Paper Products	1.533	0.838	Š0.090
Printing and Publishing	1.036	0.888	Š0.424
Chemical Products	1.964	1.184	Š0.014
Petroleum and Coal Products	1.458	1.055	0.188
Plastic Products	1.490	0.873	Š0.060
Rubber Products	1.454	0.775	Š0.073
Leather Products	1.813	0.562	Š0.251
Ceramic, Stone, and Clay Products	1.511	0.830	Š0.129
Iron and Steel	1.585	0.796	Š0.028
Nonferrous Metals	1.374	1.163	Š0.021
Metal Products	1.199	0.782	Š0.099
General Machinery	1.234	0.960	Š0.098
Computers	1.479	0.995	
Electrical Machinery	1.530	0.806	Š0.161
Communication Equipments	1.611	0.944	
Motor Vehicles and Parts	1.265	0.848	0.094
Other Transportation Equipments	1.475	0.962	
Precision Instruments	1.696	1.057	Š0.149
Miscellaneous Industries	1.607	0.781	Š0.027
Average	1.438	0.873	Š0.107

Notes:

1) according to the Standard Industy Classification for Japan, Version 11

2) See the main text for the explanation of these variables.

3) Growth rate of shipments in establishments with at least 4 employees during 1999Š2001, calculated from the Census of Manufactures by METI. Industry Classification is based on JSIC Version 10.