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A Preliminary Analysis Concerning Knowledge Creation and Performance of R&D-oriented SMEs under Uncertainty

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Abstract

Both R&D (Research & Development) and patent applications are important activities that form the foundation of innovation creation in companies. This study analyzed the direct impact of patent application activities, which are considered outcomes of knowledge creation, on the performance of R&D-oriented high-tech small and medium-sized enterprises (SMEs) that support Japan's core industries.

The results showed that for SMEs that filed at least one patent in the 2010s, as the number of patent applications increases, (i) the firm's sales per employee increases and also (ii) the rate of change of sales in the year affected by COVID-19 becomes higher. In addition, the age of the firm was found to significantly contribute to the improvement in sales per employee, suggesting that continuous knowledge creation activity tends to improve firm performance.

Keywords: SME, Knowledge Creation, Patent, Innovation, Sales per Employee, Covid-19

1 Introduction

A country's economy is driven by its private sector companies, the majority of which are small and medium-sized enterprises (SMEs). In Japan, there are currently more than 3.3 million SMEs, creating about 70 percent of all the jobs in Japan [1]. One of the most important roles of SMEs is that their contribution to innovations in our economic system. In fact, startup companies with innovative products or services, which are attracting attention as the flag-bearers of new industries, are SMEs at the time of their establishment. In these days, enforcement of ecosystems to foster startups has become an urgent political issue in many countries, under rapidly changing business environment full of uncertainty ([2], [3]). On the other hand, innovative SMEs, which do not grow rapidly but lead highly specialized niche markets, are also indispensable. For example, in the manufacturing sector in Japan, many SMEs support the basis of the industry, either as “producers of specialized parts and components” or as “providers of sophisticated services or technologies” [4]. This paper focuses on the relationship between patenting activity and performance for such high-tech SMEs belonging to so-called "supporting industries" with unique technologies and R&D capabilities.

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2 Former Studies and Research Objectives

In recent years, climate warming, the spread of infectious diseases like Covid 19 and regional military conflicts have occurred in succession, increasing business uncertainty. In such environments, dynamic capabilities, i.e., "the organizational ability to reconfigure and integrate its resources and capabilities to maintain competitive advantage in a changing environment" have become increasingly important [5]. When external changes render previously successful products, services, or business models ineffective, the rapid reconfiguration of firm resources to develop their substitutes becomes essential. The core processes of dynamic capabilities are "sensing", "seizing" and "transforming", with the underlying foundation being the company's ability for exploration and exploitation [6].

This dynamic capability is closely related to knowledge creation within a company. The SECI model, proposed by Nonaka and Takeuchi [7], is widely recognized for its emphasis on the process by which new knowledge is created through the mutual conversion of tacit and explicit knowledge within and outside the organization. Companies that actively create and manage knowledge are likely to possess excellent absorptive capacity and application capabilities of them, which provide a basis for a firm's rapid sensing, seizing, and transforming abilities in response to external changes. Therefore, knowledge creation activities support dynamic capabilities, and the existence of dynamic capabilities enhances the speed and quality of knowledge creation, forming a complementary relationship ([8], [9]).

In R&D oriented companies, some of the results of knowledge creation are filed for and held as patents. Intellectual property activities enhance the uniqueness and "resistance to imitation" of a company's resources. They also promote external collaboration and new business development while strengthening the resource reconfiguration function. Intellectual property rights also serve as a source of trust and negotiating power when companies pursue open innovation, which accelerates the creation of further new knowledge by introducing external technologies and collaborating with other companies ([5], [10]). Consequently, the long-term performance of these companies is expected to improve.

In Japan, the proportion of SMEs engaged in intellectual property (IP) activities is extremely low. Past studies have suggested, however, that patent applications and registrations can establish competitive advantages and improve productivity for such enterprises [11]. Among R&D-oriented SMEs active in niche markets, strategies to maintain the secrecy of inventions within the firm, rather than publicly exposing them through patent applications, may be adopted. In other words, not all SMEs with active knowledge creation will apply for patents. However, SMEs that own and utilize patents are considered active in knowledge creation. This enhances dynamic capabilities and contributes to innovation promotion, resulting in improved business performance. Yamauchi pointed out that new patent applications have a positive effect on firm growth based on a systematic literature review [12] while Motohashi showed that patent applications have a strong positive relationship with the growth rate of SMEs by analyzing enterprise census database [13]. In addition, it is shown that patent applications enhance the possibility to realize product innovations in R&D-intensive SMEs ([14], [15]). However, in Japan, there exists quite a little study concerning the empirical evidence concerning direct relationship between patent applications and productivity in SMEs.

This paper conducts a preliminary analysis of the relationship between patent application activities, which serve as a proxy indicator of knowledge creation, and firms' sales per employee, which have close relationship to productivity for R&D-oriented SMEs. As will be discussed later, the data used for this analysis has several missing items, such as the R&D expenditure ratio. The results of our analysis are limited in meaning, however, are considered a meaningful first step. Additional follow-up surveys to overcome these limitations are currently underway.

Improving firm performance based on knowledge creation is expected to strengthen resilience to changes in the business environment, such as those caused by the Covid-19 pandemic. In this study, we also attempt to analyze the relationship between patent filing activities and sales change rates during the Covid-19 pandemic using commercially available firm performance data.

3 Dataset

In this study, as a group of high-tech SMEs with strong R&D capabilities in Japan, we focus on SMEs selected for the Go Tech Program (formerly the “Supporting Industry Program”), which is a government subsidy program for R&D support (selected years: 2006-2021). In addition, we also targeted the SMEs selected for the "300 Vigorous Monodukuri (manufacturing) SMEs" (2006-2009: selected by the Small & Medium Enterprises Agency in Japan)). The former program provides financial support for up to three years for research and development, prototyping, and sales channel development conducted by SMEs in collaboration with public research institutes and universities [16]. Since the maximum amount of financial support is relatively large (97.5 million yen for 3 years, 2/3 subsidy), the selected SMEs are publicly announced on the internet each year. We have compiled this information to create a list of target SMEs.

As for the performance data, we used the "Corporate Information Data (3,000 bytes)" commercially provided by Tokyo Shoko Research (TSR). In addition to performance data such as sales and profits, it includes additional data on business partners and CEO attributes such as gender, age and educational background of CEO.

Concerning patent data, we used a commercial database (Hitachi SR Partner Lite) to conduct comprehensive search for patent applications filed to the Japan Patent Office in which the target SMEs are the applicants. To eliminate applications filed by different companies with the same name, sufficient time was spent on identifying patents of target SMEs.

4 Variables and Hypotheses

In this paper, we conduct a preliminary analysis of the effect on firms' performance of knowledge accumulated within the firm over a relatively long period of time. More specifically, for patent applications, we focus on the total number of applications filed in the 2010s (2010-2019).

In Japan, the impact of Covid-19 began to appear significantly in early 2020. Concerning sales per employee, we averaged the data from 2018 to 2019, before Covid-19 pandemic, to measure the performance under relatively stable business conditions. On the other hand, sales in fiscal 2020 are expected to be significantly affected by Covid-19. Therefore, we decided to focus on the rate of change in sales in fiscal 2020 compared to the previous period. The hypotheses in this

study are as follows.

The results of knowledge creation in R&D-oriented SMEs are often (though not always) filed as patents. It is presumed that companies that consistently create knowledge and enhance their innovation capabilities will gain greater earning power.

H1: Firms with a higher number of patent applications will have higher sales per employee.

On the other hand, inventions and technologies for which it is difficult to detect "imitation by other companies" (such as production technologies within a factory) may sometimes not be filed as patent if disclosure is considered to be disadvantageous. Even in such cases, it is assumed that the internal knowledge related to such hidden technologies will accumulate and make the firm more innovative as it ages. By the way, it is well known that companies with a larger number of employees tend to have higher sales per employee. While controlling for the firm size, we propose a second hypothesis regarding firm age.

H2: Firms with a higher age have higher sales per employee.

In addition, it can be inferred that companies with active knowledge creation are more resilient to significant changes in the business environment.

H3: Firms with a higher number of patent applications suffered less sales damage during the period with the Covid-19 pandemic.

5 Basic Statistics and Regression Analysis

5.1 Distribution of basic variables

Under the screening policy described in the section 3, the total number of firms for which "sales per employee" could be calculated was 1,896 in our dataset. The average number of employees is 121 while the median is 69. By definition, small and medium-sized manufacturing enterprises in Japan need only meet one of the following conditions: either “capital of 300 million yen or less” or “300 employees or less”. Therefore, 14 firms with more than 1,000 employees are included in the distribution.

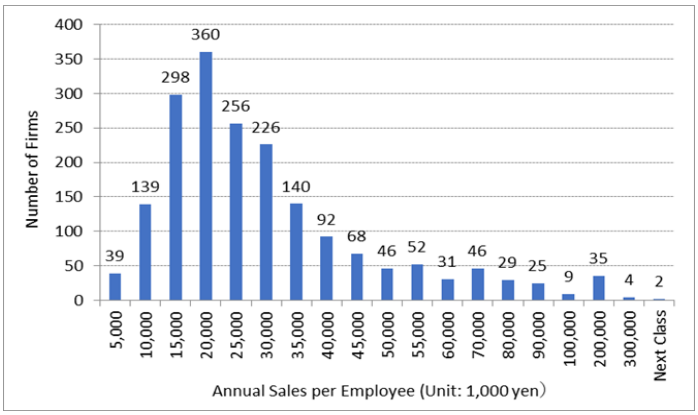

Figure 1: Distribution of sales per employee (prepared by the author)

The distribution of "sales per employee" for our target SMEs is shown in Figure 1. The mean is 29.02 million yen/person while the median is 22.13 million yen/person. Like the number of employees, the distribution has a long tail on the right side. A similar tail can be found in the “2016 White Paper on Small and Medium Enterprises in Japan”, but its mean is about 32 million yen/person which is larger than that in this dataset. The reason might be a longer tail of the distribution than our dataset [17].

As can be seen from the screening definition, most of the firms in this study belong to the manufacturing sector, but also include firms in the service sector (IT, R&D support, etc.) and the wholesale sector (including manufacturing wholesalers). In the regression analysis described below, we introduce eight different industry dummy variables.

Finally, the distribution of the number of applications to Japan patent office (in the 2010s) is shown (Figure 2). The average number of patent applications is 11.1 while the median is 3 because of a highly skewed distribution similar to previous figures. Among our target firms, 71% of all companies filed at least one application. Companies that have not filed a single patent application in those 10 years are unlikely to be engaged in formal research and development. It is plausible that their business model and management style might be somewhat different from those of patenting firms. In the following analysis, we focus on firms that have filed at least one patent application to verify our hypothesis.

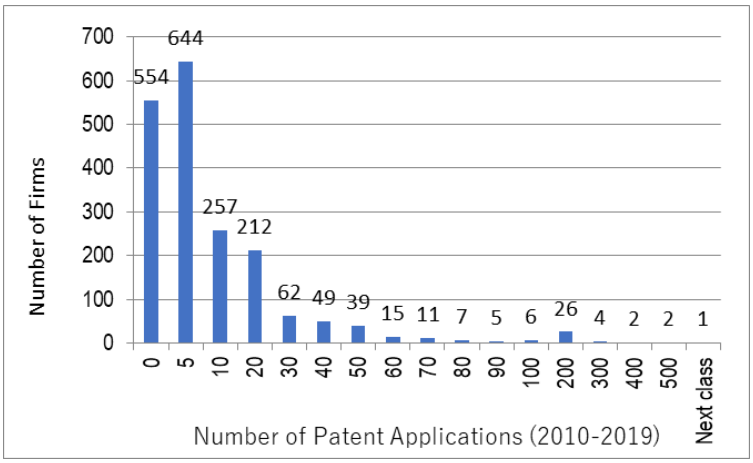

Figure 2: Distribution of patent applications (2010～2019) (prepared by the author)

When considering the corporate governance, the influence of the CEO is expected to be greater in an SME than in a large firm. In the regression analysis that follows, we add basic CEO characteristics such as gender, age, and educational background (whether they have a graduate degree or not) to control for their influence. Furthermore, we add dummy variables for industrial sector and firm location (region) to test the hypothesis.

5.2 Results of regression analysis

Concerning regression analysis, we adopt the following models:

(i) Sales per employee =
f(firm attributes (size, age), CEO attributes (age, gender, education),
number of patent applications, regional dummy, industrial dummy)

(ii) Sales growth rate in 2020 =
f(firm attributes (size, age), CEO attributes(age, gender, education),
number of patent applications, regional dummy, industrial dummy)

The basic statistics for the variables in the above equations are as follows.

Table 1: Basic Statistics (prepared by the author)

Variable	Obs.	Mean	Std. Dev.	Min	Max.
Annual sales per employee (unit: 1,000 yen)	1,895	28,893	25,631	259.75	302,278
Number of employees	1,895	122	176	1	2,090
Firm age	1,895	61.2	26.3	6	156
Number of patent applications (2010-2019)	1,893	11.6	30.4	0	628
Age of CEO	1,670	63.5	10.9	32	98
Gender of CEO (Male: 1, Female: 0)	1,882	0.96	0.18	0	1
Educational background of CEO (Master or Ph.D.: 1, else: 0)	1,621	0.07	0.25	0	1

As for regional dummies, we divided Japan into 11 regions based on the districts used for proportional representation elections in the House of Representatives. Concerning industry dummies, we introduced eight categories (Chemicals & Petroleum, Metals, Electrical, Electronics & Telecommunications, Transportation Equipment, IT, Wholesale, and Professional Services) based on the industry classifications of TSR database. By using these dummies, we control regional effects and technological opportunities by industry.

The variables adopted in the above model are considered to be related to various activities of knowledge creation and innovation in SMEs, as well as to their business performance. According to comprehensive analyses of corporate data including large companies, many studies suggest that larger companies are more active in creating innovations and are more productive. Therefore, we adopted company size as a necessary control variable. On the other hand, the contribution of company age may be positive or negative, as young companies, such as startups, are likely to engage in more vigorous knowledge creation, while mature companies are likely to engage in more efficient creation. In principle, CEOs in SMEs are considered to have a relatively greater influence than those in large companies. We included a CEO attribute that may greatly influence knowledge creation and innovation in SMEs. Finally, we also included region and industry as control variables.

Unfortunately, our dataset does not include the "ratio of engineers to total employees" or the "R&D expenditure ratio," both of which are expected to influence R&D activities. In some SMEs, usually very small ones, R&D is incorporated into daily routines, so the latter is unclear. In this paper, as an initial trial, we conducted a preliminary analysis without these variables. From an endogeneity perspective, it is important to note that the contribution of patent applications in this analysis may appear stronger than the full model.

In estimating the regression model, we performed logarithmic transformations on variables with skewed distributions and performed robust estimation using STATA. Table 2 presents the result of the regression analysis for equation (i). Firm age and the number of patent applications have significant and positive contributions, which supports hypotheses H1 and H2. In addition, it may be interesting that the age of CEO is significant with a negative coefficient, however, the contribution is limited since the absolute value of beta is small.

Table 2: Results of regression analysis (prepared by the author)

Dependent Variable: Annual Sales per Employee (log) (Robust linear regression: regional dummies, industrial dummies and a constant are omitted.)						
Variables	Coef.		Robust Std. Err.	t	P>t	beta
# of Employees (log)	0.058	***	0.022	2.64	0.008	0.104
Firm Age (log)	0.341	***	0.068	5.02	0	0.247
# of patent applications (log)	0.095	***	0.019	4.92	0	0.146
Age of CEO (log)	-0.003	**	0.002	-2.01	0.045	-0.055
Gender of CEO	-0.001		0.154	-0.01	0.995	0.000
Educational Background of CEO	-0.078		0.090	-0.86	0.39	-0.029
Num. of observations: 1,105 Adj. R-squared: 0.251 Significance: *** 1%, ** 5%, * 10%						

On the other hand, in Table 3, the result of regression analysis concerning sales growth rate in fiscal year 2020 is shown. Since the adjusted R-squared value is small, explanatory power is limited, however, it appears that the number of patent applications has a significant and positive contribution.

Table 3: Results of regression analysis (prepared by the author)

Dependent Variable: Sales growth rate in 2020 (log) (Robust linear regression: regional dummies, industrial dummies and a constant are omitted.)						
Variables	Coef.		Robust Std. Err.	t	P>t	beta
# of Employees (log)	-0.006		0.009	-0.63	0.527	-0.034
Firm Age (log)	-0.031		0.023	-1.38	0.169	-0.075
# of patent applications (log)	0.012	**	0.006	2.11	0.035	0.064
Age of CEO (log)	-0.025		0.046	-0.54	0.586	-0.021
Gender of CEO	-0.027		0.056	-0.48	0.631	-0.017
Educational Background of CEO	0.016		0.032	0.5	0.62	0.019
Num. of observations: 1,053 Adj. R-squared: 0.030 Significance: *** 1%, ** 5%, * 10%						

6 Summary and Discussion

In this preliminary analysis, we found that the results suggest the positive impact of knowledge creation in R&D-oriented SMEs on "sales per employee" and the resilience under uncertainty. In Model (i), the results show that firm age contributes the most. Since our data was collected exclusively from high-tech SMEs in Japan's top tier, it is likely that these firms have continuously evolved their products and services, improving their capability for knowledge creation as they have aged.

As we mentioned, a limitation of this study is that, due to data constraints, we were unable to include variables such as “the ratio of R&D expenditure” or “the proportion of engineers in the total workforce”. We conducted a supplementary questionary survey this spring and are now analyzing the data using a more refined model. We aim to validate the insights gained from this study through definitive analyses, link them to the state of knowledge creation in SMEs, and propose effective support measures in the near future.

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