Innovation and Entrepreneurship: A First Look at Linkage Data of Japanese Patent and Enterprise Census

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This paper presents the results of a comprehensive analysis of the innovation activities of the entire population of Japanese firms with the use of a linked dataset from the Establishment and Enterprise Census and the Institute of Intellectual Property Patent Database (Japan Patent Office patent application data). In 2006, approximately 1.4% of approximately 4.5 million firms filed for patents, and substantial patenting activities were observed not only in the manufacturing field but also in other sectors, such as business-to-business services and finance. In addition, firm survival and growth are regressed with patenting and open innovation (measured by the joint patent application with other firms and universities). Results show that innovation activities measured by patenting are positively correlated with firm performance. Furthermore, the relationship between patenting and survival rate is strong for large firms, whereas that between patenting and firm growth is strong for small firms.

Keywords: Enterprise Census, Patent database, Entry and exit of firms

JEL Classification: L25, O13

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I. Introduction

Productivity increase is an important factor in the economic growth of developed nations. Of the productivity of Organisation for Economic Co-operation and Development (OECD) countries, 20-40% is attributable to high-growth-rate new start-ups (OECD 2003). The importance of entrepreneurship in economic growth is stressed by Schumpeter (1934), who defines "innovation" as a new combination, which is classified into five types of activities generally categorized into new product development and adoption of a new process. Schumpeter (1942) also argues that "creative destruction" is an essential fact about capitalism. Creative destruction (*i.e.*, firms that succeed in innovation increase their market share, whereas firms with low productivity withdraw from the market) has been making a significant contribution to the economic expansion for a long time (Baumol 2010).

Along this line, the view that small- and medium-sized enterprises (SMEs) are a source of innovation is shared by every country in the world. However, empirical research on firm dynamics and its contribution to economic development shows mixed results. First, the survival rate of new firms is observed to be low. According to Bartelsman *et al.* (2005), 20-40% of new companies in 10 OECD countries disappear within two years of establishment. Furthermore, a positive correlation exists between firm entry and exit that occur together with macroeconomic fluctuations (Bartelsman *et al.*, 2005). As a result of the churning effect resulting from market fluctuations, the generation and dissolution of small inefficient firms that have not reached a sufficient scale occur simultaneously. This phenomenon can be viewed as firms simply moving through a revolving door (Santarelli, and Vivarelli 2010). Moreover, Schumpeter also provides two concepts on innovation, that is, the roles of SMEs are important with respect to creative destruction (Schumpeter Mark I) and the circumstances in which oligopolistic economic rents occur in large firms are also essential to economic dynamics (Schumpeter Mark II).

Innovation and entrepreneurship are important topics in Japan, which has a lower firm turnover rate than other OECD countries, such as European countries and the United States. The share of the entry and exit of enterprises in Japan is lower than that of the United States, and Japan's ranking in the Global Entrepreneurship Monitor for entrepreneurial spirit is approximately the lowest in the world (GEM

2010). Start-ups in Japan, particularly hi-tech start-ups with a technical background, are difficult to cultivate because of the labor market rigidity and underdevelopment of venture capital activities supplying risk money to start-up projects, among other factors (Motohashi 2010). In addition, a large firm with a substantial technological capability plays an important role in the Japanese national innovation system, and the in-house orientation of research and development (R&D) of large firms may hinder entrepreneurial activities. For hi-tech start-ups to grow, they should tie up with a large firm; however, large Japanese firms are generally not proactive in assimilating new technology using start-ups. Given the growing competitive pressure from Korean and Chinese firms, large Japanese firms become increasingly difficult to follow through with in-house R&D style. Large firms should form alliances with universities and start-ups to accelerate its innovation speed; moreover, the promotion of hi-tech start-ups is important for changing Japan's innovation system from large firms' in-house style to a network style (Motohashi 2005).

In this paper, we report the results of the analysis of innovation and company dynamics with the use of a dataset that links the Establishment and Enterprise Census and the Institute of Intellectual Property (IIP) Patent Database. The objective of this research is to derive new implications related to the issue of whether new firms are a source of economic growth (source-of-growth firms) or belong to the "revolving-door" type. Although both apparently exist in combination, in this study, we take the position that source-of-growth firms are firms that exert effort toward patent application and/or open innovation. Patent applications can be considered a variable that reflects the effort of a firm toward technological innovation. We examine the distribution of the patenting activities of the entire population of Japanese firms according to size, age, and industry type and the influence of these activities on the survival and growth of the firms. We also investigate the influence of open innovation activities, such as R&D collaboration with other firms and universities, on firm performance.

This paper is structured as follows: First, we introduce the data source in this study, that is, the Enterprise and Establishment Census data and the Japan Patent Office (JPO) patent database, called IIP Patent Database (Goto, and Motohashi 2007). Next, we present the results of linking these datasets based on company name and address information and discuss the descriptive statistics resulting from the linkage data. Then, we show the results of the quantitative analysis of the relationship of open innovation and patent applications (drawn from the linkage data) with the survival rate and growth speed of firms. Finally, we summarize and discuss our findings and provide policy implications.

II. Description of Enterprise and Establishment Census and IIP Patent Database

A. Enterprise and Establishment Census

The Enterprise and Establishment Census encompasses all business establishments in Japan. Along with providing base statistical data, such as the number of establishments and employees, the Enterprise and Establishment Census is also used as the survey body information set for governmental statistical surveys. This survey is conducted twice every five years. This survey was originally named Establishment Census until July 1991; from the October 1996 survey onward, the name was changed to the Enterprise and Established Census. Owing to the addition of "address of head office" as a survey item in the October 1996 survey, business establishments can be grouped by company name. The 2006 survey is the last Enterprise and Establishment Census, and a new survey framework based on data collection at the enterprise level has been developed for "The Economic Census" in 2012. A preparatory survey was conducted in 2009 to prepare for the survey, and the data for 2009 and 2012 have been published already.

Table 1 shows the trend in the numbers of business establishments and employees from the Enterprise and Establishment Census. The number of business establishments decreased from 6,290,730 in 1981 to 5,722,559 in 2006.[1] By contrast, the total number of employees showed an increasing trend until 1991 and has since then seesawed between 52 million and 55 million. Therefore, the average employee number per business establishment (business establishment size) showed an increasing trend. Furthermore, the business establishments included all business entities engaging in economic activities, and unpaid family workers (family-run businesses) were included in the number of

[1] The number of establishments increased in the 2009 Economic Census Preparatory Survey (5,886,193); such an increase may be due to the change in survey methodology. The number of establishments is assumed to decrease over time because the 2012 Economic Census showed a decreasing trend (5,768,489) again.

TABLE 1

NUMBERS OF ESTABLISHMENTS AND EMPLOYEES IN THE CENSUS

Date	Number of Establishments (Est)		Number of Employees (Emp)		Emp/Est
1981.7.1	6,290,703		45,961,266		7.31
1986.7.1	6,551,741	0.82%	49,224,514	1.38%	7.51
1991.7.1	6,559,337	0.02%	55,013,776	2.25%	8.39
1994.4.20	6,550,245	−0.05%	54,366,015	−0.39%	8.30
1999.7.1	6,203,249	−1.08%	53,806,580	−0.21%	8.67
2001.10.1	6,138,312	−0.52%	54,912,703	1.02%	8.95
2004.6.1	5,728,492	−2.28%	52,067,396	−1.76%	9.09
2006.10.1	5,722,559	−0.05%	54,184,428	2.01%	9.47

employees. In other words, many business establishments with zero employees (non-employee establishments) were included in this sample.

Company and business establishment numbers (identification numbers) from past surveys are required at the time of conducting the research to consolidate the panel data for the Enterprise and Establishment Census. In this survey, business establishments are the main statistical unit, and linking panel data at the business establishment level using the establishment identification numbers is possible. However, compiling enterprise-level panel datasets is complex. From the 1996 survey onward, the names and addresses of enterprise headquarters are surveyed for all establishments, allowing the aggregation of establishment data at the enterprise level. However, this enterprise dataset cannot be linked inter-temporally because of the lack of an enterprise identification system. Therefore, we treat the firms with the same establishments between two periods to be identical.

B. IIP Patent Database

The IIP Database is compiled based on the Consolidated Standardized Data, which is made public twice a month by the JPO. The Consolidated Standardized Data includes patent information recorded as a text file with SGML and XML tags. In this study, these text files are converted into an SQL database to facilitate the statistical processing of the data. Furthermore, information that is believed to be needed most by researchers is released as a CSV-format text file. The dataset used for this paper is the version containing all patent applications from January 1964 until October 2009 (15th public release of Consolidated Standardized Data 2009).

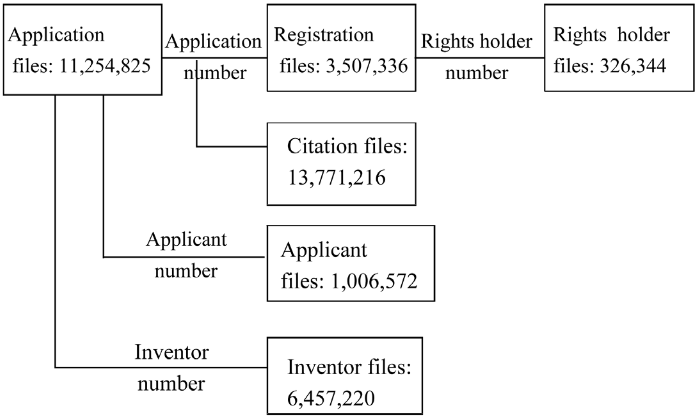

FIGURE 1
STRUCTURE OF IIP PATENT DATABASE

The data released publicly in CSV format as the IIP Patent File include patent application data (application number, application date, examination request date, technological field, and number of claims); patent registration data (registration number and rights expiration date); applicant data (applicant name, applicant type, and country/prefecture code); rights holder data (rights holder name); citation information (citation/cited patent number); and inventor data (inventor name and address) (Goto, and Motohashi 2007). Figure 1 shows the database structure and number of data for each table. For example, the database illustrated in Figure 1 includes the data for 11,254,825 patent applications, among which 3,507,336 patents are registered. A table relating to the applicant and rights holder is linked to each of these applications. Moreover, citation data include the data related to examiner citations, that is, the past patent literature that the examiner cites as their reason for rejecting the patent application.

Based on the raw data from the Consolidated Standardized Data by JPO, the IIP Patent Database is created with substantial effort to provide ready-made usable data for researchers. The most important points for revision arise from the inconsistency in the recording method of applicant names in the raw data. For example, in the 1960s data, the names are displayed in katakana (Japanese characters), whereas more recent data are recorded in kanji (Chinese characters). Thus, merging records under the same name is impossible using the original text information. In addition, owing to the changes in the company names and notation methods (such as "incorporated" or "inc."), modifications are required to ensure that the same company under different expressions are recognized as the same ones.

This study utilizes the JPO applicant ID codes. However, given that this code underwent several changes before it became the present-day nine-digit code, we had to rectify this first. Notably, the JPO applicant ID code may be suffering from false-negative errors (two different codes being assigned to the same person even if only one should have been assigned); however, no false-positive errors (the same code being assigned to two different records) exist because this code is manually assigned by the patent examiner.

First, we classified the companies by applicant type (*i.e.*, individual inventor, company, nonprofit organizations, or universities) with the use of applicant name information. Then, we extracted only the company applicant names and assigned them our own ID numbers by assuming that the companies that existed in the same municipality with the same company name were actually the same company (Thoma *et al.*, 2010). Moreover, false negatives could occur in cases wherein company name standardization using this method is insufficient or in cases wherein the company changed its name. False positives could also occur in cases wherein two different companies with the same name exist in the same area. Linking this patent data with enterprise and establishment census data mitigates this problem, as discussed in the subsequent section.

III. Data linkage of establishment census and patent database

A. Linkage method and results

The linkage of Enterprise and Establishment Census and IIP Patent Database was conducted using the identical company name (standardized name) and location (municipality level). The head office name and address could be obtained from the Enterprise and Establishment Census in the 2001, 2004, and 2006 surveys. In the other years, linking using the company name was impossible; thus, we decided to link the panel data and the patent database for two surveys in 2001 and 2006 (2004 was a simplified survey year). In the Enterprise and Establishment Census, each establishment was categorized into three types, as follows: (1) a single unit establishment

TABLE 2
NUMBER OF ESTABLISHMENTS BY TYPE

	Single Est.	Headquarter	Branch	Total
2001 Survey	4,722,947	229,436	1,185,929	6,138,312
2006 Survey	4,238,068	228,664	1,255,827	5,722,559

firm (Single Est.), (2) the head office of a firm with multiple establishments (Headquarter), and (3) a branch of a firm with multiple establishments (Branch). The numbers of business establishments in the 2001 and 2006 surveys by type are provided in Table 2.

Patent applications are usually managed by an entire company, instead of an individual establishment; thus, applicant information from patent data should be linked with a headquarter of multiple-establishment firm or a single-establishment firm. However, several cases wherein the address of the applicant is not the address of the firm's head office exist. In addition, the names and addresses in the IIP Patent Database and/or Enterprise and Establishment Census data may also be incomplete. Therefore, we matched two datasets using the branch and head office data. In the process of name cleaning of the patent database, only one firm falls under each name and location (municipality level) set. However, several cases wherein a firm from the IIP Patent Database is linked with multiple firms in the Enterprise and Establishment Census data exist. In such cases, the priorities were set as head office > individual business establishment > branch office to ensure a one-to-one link. As a result, 1.33% of all the firms in 2001 and 1.42% of all the firms in 2006 have one or more patent applications. From the number of patents applied, approximately 60% of patents out of approximately 10 million patent applications were matched with the Enterprise and Establishment Census data. Furthermore, when patent applicants from overseas and patents applied for by individual inventors were excluded and when the application year was limited to until 2006, the total number of patents was 8,801,613. Of these, 5,772,461 were matched from the 2006 data, which indicates that 65.3% of the patents were covered.

Linkage could not be properly made in several cases because of discrepancies in the spelling of company names and incomplete addresses. Several companies that submitted patent applications were treated as firms without patents. However, discontinued businesses that did not exist in 2006 were also included in approximately 35% of

TABLE 3
LINKING PERFORMANCE WITH PATENT DATABASE

	2001	2006
No. of Firms	5,082,267	4,627,530
With Patents	66,852	64,640
% With Patents	1.32%	1.40%
No. of Patents	6,202,304	5,752,461
% of Coverage	62.86%	58.30%

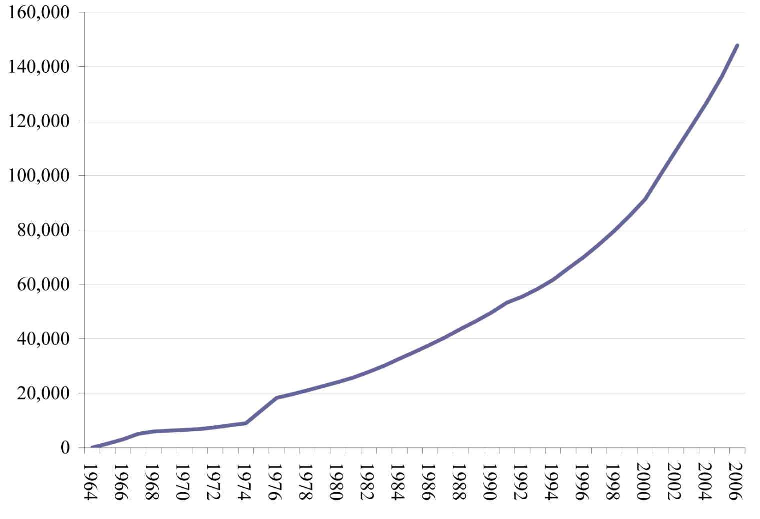

FIGURE 2
CUMULATIVE NUMBERS OF FIRMS BY THE LAST YEAR OF PATENT APPLICATIONS

the unmatched patents. To conduct an assessment on this point, we made a firm-level analysis of the IIP Patent Database. First, the number of applicants, excluding individual inventors who were located in Japan and applied for at least one patent by 2006, was 167,430. As shown in Table 3, the number of companies that we were able to link to the Enterprise and Establishment Census data was 64,630, which was only less than half of the total number of applicants. Figure 2 shows the application status of the 167,430 applicants and illustrates the cumulative numbers of firms by the last year of patent applications. For example, the number of applications corresponding to year 2000 was

TABLE 4
RATIOS OF PATENTING FIRMS BY SIZE (2006 DATA)

Size	With Patents		Without Patents	All
0	28	(0.0%)	1,385,156	1,385,184
1	920	(0.1%)	627,732	628,652
2	2,155	(0.4%)	501,320	503,475
3	2,336	(0.6%)	374,286	376,622
4–5	4,724	(0.9%)	493,577	498,301
6–10	9,217	(1.7%)	544,238	553,455
11–100	32,688	(5.2%)	592,940	625,628
101–1,000	11,343	(21.4%)	41,780	53,123
1,001–	1,229	(39.8%)	1,861	3,090

91,315, which is the number of firms that applied for patents in 2000 or before but did not apply after 2000. Firms that had not filed a patent application for a long period was unlikely to still exist in 2006. The number of firms that had not applied for a patent for more than 10 years was approximately 70,000 (firms that last filed an application in 1996 and had not filed a new patent application until 2006), and the remaining number was approximately 97,000. When 64,000 of these patent applications were considered to be linked, a certain level of linkage performance was achieved. The number of companies shown to be without patents in Table 3 is approximately 4.5 million; thus, approximately 30,000 (97,000-64,000) of the unidentified patents do not make a substantial bias.

B. Descriptive statistics of the distribution of patenting firms

In this section, the linkage data given in the previous section is used, and an analysis of how the ratio of companies applying for patents varies depending on company size, age, and industry type is presented. First of all, with respect to company size by the number of employees, the larger the company is, the higher the ratio of companies applying for patents (Table 4).

However, we are unable to observe a clear trend in relation to the company age and ratio of patent applications. Table 5 shows the ratio of patent applications by the establishment year of companies.[2]

[2] The Business Establishment and Company Statistics only provide data on the establishment year of business establishments; thus, when a company is composed of multiple business establishments, we considered the establishment

TABLE 5
RATIOS OF PATENTING FIRMS BY ESTABLISHMENT YEAR (2006 DATA)

Establishment Year	With Patents		Without Patents	All
–1954	8,273	(1.8%)	460,419	468,692
1955–64	7,934	(2.2%)	345,260	353,194
1965–74	12,355	(1.9%)	650,224	662,579
1975–84	11,052	(1.4%)	789,711	800,763
1985–94	12,989	(1.3%)	962,876	975,865
1995–99	5,332	(1.0%)	505,513	510,845
2000	1,302	(1.2%)	111,691	112,993
2001	1,080	(0.9%)	113,962	115,042
2002	1,005	(1.0%)	104,480	105,485
2003	985	(0.8%)	124,388	125,373
2004	1,009	(0.8%)	131,260	132,269
2005	745	(0.6%)	126,226	126,971
2006	457	(0.4%)	108,249	108,706

TABLE 6
RATIOS OF PATENTING FIRMS BY INDUSTRY (2006 DATA)

Industry Type	With Patents		Without Patents	All
Agriculture	193	(1.6%)	12,013	12,206
Forestry	25	(1.8%)	1,411	1,436
Fisheries	25	(1.1%)	2,312	2,337
Mining	71	(3.1%)	2,309	2,380
Construction	5,810	(1.2%)	491,276	497,086
Manufacturing	29,117	(6.5%)	446,897	476,014
Electricity, Gas, Heat Supply, and Water	91	(12.9%)	708	799
Information and Communications	3,251	(8.7%)	37,435	40,686
Transport	742	(0.9%)	85,209	85,951
Wholesale and Retail Trade	15,916	(1.4%)	1,163,064	1,178,980
Finance and Insurance	257	(0.7%)	34,280	34,537
Real Estate	845	(0.3%)	289,647	290,492
Eating and Drinking Places, Accommodations	608	(0.1%)	677,437	678,045
Medical, Health Care, and Welfare	249	(0.1%)	264,929	265,178
Education, Learning Support	326	(0.2%)	131,486	131,812
Compound Services	258	(1.7%)	15,300	15,558
Services, N.E.C.	6,856	(0.8%)	907,177	914,033

Although the ratio of patent applications among firms that have been around longer is slightly higher than those among younger firms, the difference was not considerable compared with the difference in the

year of the oldest business establishment to be the establishment year of a company.

TABLE 7
RATIOS OF PATENTING FIRMS BY INDUSTRY
(2006 DATA; MANUFACTURING IN DETAIL)

Manufacturing Industry Type	With Patents		Without Patents	All
Manufacture of Food	1,609	(4.0%)	40,167	41,776
Manufacture of Beverages and Tobacco	404	(6.6%)	6,084	6,488
Manufacture of Textile Mill Products	807	(3.4%)	23,480	24,287
Manufacture of Apparel	760	(2.4%)	32,332	33,092
Manufacture of Lumber and Wood Products	473	(3.1%)	15,382	15,855
Manufacture of Furniture and Fixtures	499	(1.9%)	25,900	26,399
Manufacture of Pulp, Paper, and Paper Products	834	(8.1%)	10,286	11,120
Printing and Allied Industries	942	(2.6%)	36,930	37,872
Manufacture of Chemical and Allied Products	1,401	(34.2%)	4,101	5,502
Manufacture of Petroleum and Coal Products	95	(19.8%)	479	574
Manufacture of Plastic Products	1,972	(10.4%)	19,019	20,991
Manufacture of Rubber Products	383	(7.4%)	5,178	5,561
Manufacture of Leather Tanning and Leather Products	199	(3.0%)	6,671	6,870
Manufacture of Ceramic, Stone, and Clay Products	1,324	(7.2%)	18,285	19,609
Manufacture of Iron and Steel	461	(8.9%)	5,187	5,648
Manufacture of Non-Ferrous Metals and Products	408	(10.7%)	3,813	4,221
Manufacture of Fabricated Metal Products	3,224	(5.3%)	60,628	63,852
Manufacture of General Machinery	5,706	(10.7%)	53,230	58,936
Manufacture of Electrical Machinery and Equipment	2,013	(13.8%)	14,604	16,617
Manufacture of ICT Equipment	499	(17.0%)	2,933	3,432
Electronic Parts and Devices	1,172	(13.6%)	8,595	9,767
Manufacture of Transportation Equipment	1,332	(7.1%)	18,700	20,032
Manufacture of Precision Instruments and Machinery	1,205	(15.6%)	7,702	8,907
Miscellaneous Manufacturing Industries	1,395	(5.1%)	27,211	28,606

ratios by company size. A positive correlation between company scale and company age can be assumed. However, many old companies remain small in size. These companies are considered to have a stable business in the niche market. In many cases, these companies are strangers to the kind of innovation activities observed in patents. Innovation activities go hand in hand with risk; thus, on the flip side of having the chance of becoming a large successful company is a strong possibility of failure, which drives a company out of business. Therefore, the possibility of an innovative company to remain small in scale for a long time is assumed to be small.

Tables 6 and 7 show the ratio of firms with patents by industry. Of the approximately 65,000 firms applying for patents, 27,000 belong to the manufacturing industry. Patent applications, which are the outcomes of technological innovation, are typically observed in the

TABLE 8
ENTERING, CONTINUING, AND EXITING FIRMS BY SIZE
(FIGURES IN PERCENTAGE (%))

Size	Entering	Continuing		Exiting
		2001	2006	
All Firms	1.07	1.47	1.49	0.93
0	0.01	0.00	0.00	0.00
1	0.26	0.07	0.12	0.19
2	0.57	0.26	0.38	0.47
3	0.76	0.48	0.58	0.68
4–5	1.03	0.82	0.92	1.05
6–10	1.46	1.55	1.74	1.68
11–100	3.05	5.55	5.94	3.83
101–1,000	11.08	24.00	23.48	12.65
1,001–	21.18	47.49	41.93	30.22

TABLE 9
ENTERING, CONTINUING, AND EXITING FIRMS BY ESTABLISHMENT YEAR
(FIGURES IN PERCENTAGE (%))

Establishment Year	Entering	Continuing		Exiting
		2001	2006	
–1954	—	1.78	1.78	0.80
1955–64	—	2.19	2.25	0.92
1965–74	—	1.80	1.86	0.94
1975–84	—	1.36	1.36	0.91
1985–94	—	1.29	1.29	1.06
1995–99	—	0.93	0.97	0.96
2000	—	0.73	0.94	0.70
2001	1.05	—	—	—
2002	0.99	—	—	—
2003	0.79	—	—	—
2004	0.78	—	—	—
2005	0.59	—	—	—
2006	0.42	—	—	—

manufacturing industry. However, many patent applications are filed by firms belonging to the wholesale and retail trade, construction, and information and communications industries. Furthermore, with respect to patenting company ratio by industry, the information and communications industry exceeds the manufacturing industry. A more intensive examination of the manufacturing industry shows that the

TABLE 10

ENTERING, CONTINUING, AND EXITING FIRMS BY INDUSTRY
(FIGURES IN PERCENTAGE (%))

Industry type	Entering	Continuing		Exiting
		2001	2006	
Agriculture	1.07	1.82	1.75	0.67
Forestry	2.45	1.52	1.57	1.62
Fisheries	1.62	0.65	0.97	0.49
Mining	1.37	3.46	3.21	1.61
Construction	0.90	1.22	1.22	0.84
Manufacturing	5.26	6.01	6.25	3.27
Electricity, Gas, Heat Supply, and Water	4.23	14.24	13.99	5.46
Information and Communications	6.56	9.29	9.47	6.55
Transport	0.50	0.98	0.97	0.39
Wholesale and Retail Trade	1.17	1.43	1.39	0.86
Finance and Insurance	0.52	0.82	0.87	0.53
Real Estate	0.39	0.24	0.27	0.40
Eating and Drinking Places, Accommodations	0.05	0.11	0.11	0.05
Medical, Health Care, and Welfare	0.13	0.07	0.08	0.07
Education, Learning Support	0.37	0.19	0.19	0.12
Compound Services	1.24	1.64	1.73	1.24
Services, N.E.C.	0.92	0.69	0.70	0.84

ratio of companies applying for patents in the chemical industry is the highest. This result reflects the fact that patent rights can be enforced more strongly in the chemical industry, including the pharmaceutical industry (Cohen *et al.* 2002). In addition, the ratio of patenting firms is high in the precision machinery and electronics sectors, which focus on electronics technology.

Table 8 shows the ratios of firms with patents among entering, continuing (surviving), and exiting firms between 2001 and 2006. Overall, the firms that survived in the two periods of 2001 and 2006 have the highest ratios of patents. However, from the perspective of company size, the smaller-sized category has a lower patent ratio among continuing companies. This result supports the hypothesis that innovation activities, such as patenting, go hand in hand with higher risks. By contrast, for firms on a larger scale, the patent application ratio is higher among continuing companies because they are able to absorb substantial risks backed by its substantial in-house resources.

Table 9 shows the ratios of firms with patents and indicates whether they are new/entering, continuing, or exiting companies. In the table,

TABLE 11

ENTERING, CONTINUING, AND EXITING FIRMS BY INDUSTRY
(MANUFACTURING IN DETAIL, FIGURES IN PERCENTAGE (%))

Manufacturing industry type	Entering	Continuing		Exiting
		2001	2006	
Manufacture of Food	2.54	3.90	4.06	2.17
Manufacture of Beverages and Tobacco	5.29	6.33	6.38	3.38
Manufacture of Textile Mill Products	3.11	3.36	3.34	1.22
Manufacture of Apparel	1.82	2.29	2.37	0.96
Manufacture of Lumber and Wood Products	3.12	2.81	2.97	1.40
Manufacture of Furniture and Fixtures	1.91	1.80	1.89	1.39
Manufacture of Pulp, Paper, and Paper Products	6.18	7.23	7.67	3.93
Printing and Allied Industries	2.13	2.50	2.55	1.25
Manufacture of Chemical and Allied Products	15.66	28.10	28.48	15.30
Manufacture of Petroleum and Coal Products	9.63	16.75	18.68	9.43
Manufacture of Plastic Products	7.02	9.41	9.80	4.90
Manufacture of Rubber Products	4.78	6.92	7.28	2.32
Manufacture of Leather Tanning and Leather Products	2.07	3.07	3.03	1.29
Manufacture of Ceramic, Stone, and Clay Products	4.73	6.61	7.03	3.47
Manufacture of Iron and Steel	3.91	8.67	9.05	3.94
Manufacture of Non-Ferrous Metals and Products	7.18	9.65	10.12	4.81
Manufacture of Fabricated Metal Products	3.60	5.05	5.26	2.75
Manufacture of General Machinery	8.15	9.52	9.93	6.97
Manufacture of Electrical Machinery and Equipment	10.50	11.70	12.45	6.84
Manufacture of ICT Equipment	11.18	14.45	15.36	9.90
Electronic Parts and Devices	10.35	11.79	12.40	6.37
Manufacture of Transportation Equipment	4.64	7.05	7.02	4.17
Manufacture of Precision Instruments and Machinery	12.96	13.44	13.66	8.57
Miscellaneous Manufacturing Industries	5.24	4.59	4.81	3.16

patenting firms are categorized by the company establishment year. In general, companies with earlier establishment year had higher patent application ratios.

Finally, Tables 10 and 11 present the state of firm dynamics by industry type. Table 10 clearly shows the industries that have a high ratio of company patent applications among continuing firms compared with new entrants and exiting firms (*e.g.*, manufacturing and information and communications) and the industries that exhibit the opposite pattern (*e.g.*, forestry, real estate, and medical). Details of the manufacturing industry shown in Table 11 reveal that, in most business categories, the ratios are largest for continuing firms, followed by new entrants and exiting firms.

IV. Econometric analysis of (open) innovation and firm survival and growth

In this section, we use patents as an indicator of innovation to analyze its relationship with the firm survival and growth. In addition, we construct several indicators of open innovation using the IIP Patent Database. Concretely, we determine whether a patent is applied jointly with other firms (inter-firm linkages) and/or with a university (industry-academia linkages). Furthermore, to track industry-academia linkages through the IIP Patent Database, we use inventor information and applicant information because industry-academia joint inventions were usually patented solely by the firm until 2004 when national universities in Japan were incorporated and entitled to claim patent rights (Muramatsu, and Motohashi 2012).

Table 12 shows the ratios of open-innovation firms categorized as new entrant, continuing, and exiting firms, with respect to company patent applications between 2001 and 2006. First, compared with continuing firms, exiting firms have a lower ratio of open innovation. New entrants also have lower indices than continuing firms; however, the differences are not as large as those between continuing and exiting firms. According to the empirical analyses of previously conducted studies on firms' market entry, exit, and productivity, firms with lower productivity have higher chances of discontinuation in the near future (Griliches, and Regev 1995; Baily *et al.* 1992; Matsuura, and Motohashi 2005). The presence of open innovation may represent the higher innovative capability of firms, particularly in the case of joint research

TABLE 12
ENTERING, CONTINUING, AND EXITING FIRMS AND OPEN INNOVATION
(FIGURES IN PERCENTAGE (%))

Company State	Inter-Firm Network		Industry–Academia Collaboration	
	2001	2006	2001	2006
Entering	—	41.7	—	13.2
Continuing	37.4	43.4	12.0	14.4
Exiting	33.7	—	8.1	—

TABLE 13
RATIOS OF OPEN-INNOVATION FIRMS BY SIZE
(ONLY FOR CONTINUING FIRMS, FIGURES IN PERCENTAGE (%))

Size	Inter-Firm Network		Industry–Academia Collaboration	
	2001	2006	2001	2006
0	0.0	20.0	10.0	20.0
1	23.1	29.3	8.7	10.6
2	24.1	30.1	5.1	7.3
3	20.6	27.6	4.0	6.0
4–5	22.5	29.4	4.2	6.3
6–10	24.0	32.1	4.1	6.1
11–100	33.6	41.6	8.1	11.0
101–1,000	60.1	61.1	26.8	29.3
1,001–	78.4	68.0	55.3	49.1

with universities. Open innovation also means sharing the risks associated with innovation activity with partners, particularly in the case of inter-firm collaborations. Such collaborations increase the survival rate of a firm. In addition, for continuing firms, inter-firm cooperation and industry-academia collaborations increased from 2001 to 2006, indicating that open innovation is progressing.

Table 13 shows the open-innovation indices by company size. The ratio of inter-firm linkages increases with the size of the firm. The ratio of industry-academia linkages shows a U-shaped distribution, with higher values for large-scale and small-scale firms. The results for the industry-academia linkages with respect to company size are consistent with the results based on a previously conducted survey on external R&D collaborations (Motohashi 2008).

Tables 14 and 15 show the distributions by industry. Furthermore,

TABLE 14
RATIOS OF OPEN-INNOVATION FIRMS BY INDUSTRY
(ONLY FOR CONTINUING FIRMS)

Industry Type	No. of Firms	Inter-Firm Network (%)		Industry–Academia Collaboration (%)	
		2001	2006	2001	2006
Agriculture	165	27.3	35.8	9.7	17.6
Forestry	17	17.6	29.4	11.8	11.8
Fisheries	13	15.4	23.1	7.7	15.4
Mining	75	41.3	53.3	17.3	20.0
Construction	4,972	34.0	39.7	11.1	12.2
Manufacturing	24,780	38.5	45.0	10.9	13.5
Electricity, Gas, Heat Supply, and Water	87	63.2	67.8	35.6	42.5
Information and Communications	1,860	29.1	38.1	6.8	10.3
Transport	637	41.4	50.4	8.3	8.6
Wholesale and Retail Trade	13,611	41.2	45.7	15.0	16.8
Finance and Insurance	173	37.6	44.5	11.0	12.7
Real Estate	545	23.3	29.0	4.6	5.7
Eating and Drinking Places, Accommodations	531	24.7	26.4	8.1	8.7
Medical, Health Care, and Welfare	127	22.8	29.9	8.7	15.7
Education, Learning Support	168	25.0	25.0	14.9	16.7
Compound Services	222	0.0	0.0	71.6	94.1
Services, N.E.C.	4,816	32.5	39.8	10.9	14.2

to make a time series comparison possible, we examine continuing firms only. The industries with high numbers of patent applications are the manufacturing and wholesale/retail industries; nevertheless, the open-innovation ratios increase in all industries. A comparison by business category shows that the ratios of open innovation increase for service industries, such as information and communications, electricity/gas and other public utilities, and finance and insurance, even if the number of firms in these sectors is small. A granular look at the manufacturing industry shows that inter-firm linkages mainly incre

TABLE 15

RATIOS OF OPEN-INNOVATION FIRMS BY INDUSTRY

(ONLY FOR CONTINUING FIRMS; MANUFACTURING IN DETAIL)

Industry Type	No. of Firms	Inter-Firm Network (%)		Industry–Academia Collaboration (%)	
		2001	2006	2001	2006
Manufacture of Food	1,417	25.12	29.78	9.10	12.00
Manufacture of Beverages and Tobacco	366	26.78	31.15	11.20	14.75
Manufacture of Textile Mill Products	760	37.24	44.21	9.08	11.97
Manufacture of Apparel	665	20.75	26.47	2.71	3.91
Manufacture of Lumber and Wood Products	413	29.54	34.38	7.75	10.65
Manufacture of Furniture and Fixtures	419	19.81	26.25	5.97	8.35
Manufacture of Pulp, Paper, and Paper Products	714	34.31	41.18	5.46	7.42
Printing and Allied Industries	810	28.02	34.32	5.06	6.17
Manufacture of Chemical and Allied Products	1,169	57.31	61.33	26.43	29.68
Manufacture of Petroleum and Coal Products	70	52.86	57.14	21.43	30.00
Manufacture of Plastic Products	1,693	42.35	50.97	9.45	11.70
Manufacture of Rubber Products	327	44.65	51.99	11.93	12.84
Manufacture of Leather Tanning and Leather Products	183	15.85	20.77	1.09	1.09
Manufacture of Ceramic, Stone, and Clay Products	1,167	40.36	48.41	15.77	19.88
Manufacture of Iron and Steel	398	46.98	51.76	16.58	17.84
Manufacture of Non-Ferrous Metals and Products	349	54.44	57.31	16.62	17.48
Manufacture of Fabricated Metal Products	2,803	35.39	43.74	7.53	10.31
Manufacture of General Machinery	4,809	40.53	46.60	10.63	12.89
Manufacture of Electrical Machinery and Equipment	1,611	46.74	53.01	12.04	14.65
Manufacture of ICT Equipment	413	44.07	50.12	13.32	18.16
Electronic Parts and Devices	935	45.35	54.97	12.51	17.43
Manufacture of Transportation Equipment	1,178	48.47	54.33	16.47	19.02
Manufacture of Precision Instruments and Machinery	983	40.69	46.59	13.22	17.50
Miscellaneous Manufacturing Industries	1,128	24.20	29.96	4.79	5.76

TABLE 16
SURVIVAL AND INNOVATION ACTIVITIES OF FIRMS (PROBIT MODEL)

	(1)	(2)	(3)	(4)
Patent	0.141	−0.254	−0.204	−0.389
	(24.15)**	(17.48)**	(10.42)**	(7.83)**
Log(emp)		0.094		−0.01
		(163.46)**		(5.31)**
Log(age) emp= <100			0.183	0.148
			(266.10)**	(142.60)**
Log(emp)*log(age)				0.035
				(54.50)**
Log(emp)*patent		0.108		0.143
		(24.88)**		(8.03)**
Log(age)*patent			0.122	0.06
			(17.90)**	(3.44)**
Log(emp)*log(age) *patent				−0.016
				(2.63)**
Constant	0.036	−0.141	0.118	0.084
	(1.00)	(2.79)**	(3.12)**	(2.23)*
Industry Dummy	Yes	Yes	Yes	Yes
Size Dummy	Yes	No	Yes	No
Age Dummy	Yes	Yes	No	No
Observations	5,037,471	5,037,471	4,456,259	4,456,259

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

ase in the machine industry, whereas industry-academia linkages increase in the chemical and petrochemical industries.

Table 16 estimates the survival function of companies. We conduct a probit estimation using independent variables, such as company size. We employ a dummy variable for firms with patent applications as a dependent variable, which is 0 for continuing companies and 1 for exiting companies in the period from 2001 to 2006. In addition to including the dummy variables for industry type, firm size, and firm age, we also use the scale values for size and age (taking the logarithm of each), and their cross terms are used as independent variables in several specifications.

Model (1) assesses the relationship between patent dummy and continuation of companies. Given that the coefficient is positive and statistically significant, the companies applying for patents in 2001 have a high survival probability. Model (2) includes a cross term of the logarithmic value of the patent variable and firm size as independent variable. A positive and statistically significant relationship can be observed with respect to the cross term, implying that a positive relationship exists between patenting and survival probability in large companies. However, for smaller companies, the inverse is true and a negative relationship exists (the coefficient of the patent dummy is negative). Model (3) shows the relationship with firm age. Older firms have a high probability of survival. Finally, Model (4) uses firm size and age and their cross term with patent variables. For the cross term with patents, positive and statistically significant relationships exist for firm scale and age, but the coefficients of their cross terms are negative. This result shows that the relationship between patenting and survival probability is positive when firm scale is large (firm age is larger), but such an influence decreases as firm age increases (firm scale is larger).

Table 17 uses the same dependent variables to reveal their relationship with firm growth. The dependent variable is a logarithmic value of the number of employees of continuing firms between 2001 and 2006. The dependent variable was estimated using a fixed-effect model employing balanced panel data for the two years. Model (1) shows a positive correlation between patent applications and firm growth. Model (2) uses patents and the cross term of firm size and age in 2001 and shows that the smaller and younger the company is, the stronger the positive correlation between patenting and firm growth. Models (3) and (4) show the relationship with open innovation. A relationship between open innovation and company growth is not evident based on the logarithmic values for inter-firm linkages and industry-academia linkages alone. However, we determined that, for inter-firm linkages, the smaller the firm is, the stronger the relationship of open innovation to firm growth.

A positive coefficient of patents on firm growth, particularly in smaller and younger firms, may be explained by selection bias, given that larger and older firms with patents are more likely to survive, as shown in Table 16. This finding supports the risk hypothesis of patenting, that is, firms applying for patents still face greater risks associated with commercialization of patented technology than firms without patents. Younger and smaller firms are more vulnerable to such a risk, and their survival rates become smaller compared with those of established large firms. As a result, younger and smaller firms

TABLE 17

GROWTH AND INNOVATION ACTIVITIES OF FIRMS (FIXED-EFFECT MODEL)

	(1)	(2)	(3)	(4)
Log(patent)	0.026 (7.48)**	0.260 (19.78)**	0.025 (5.24)**	0.027 (5.25)**
Log(patent)*log(emp)		−0.018 (6.59)**		
Log(patent)*log(age)		−0.058 (12.85)**		
log(univ+1)			−0.004 −0.44	0.033 −0.82
log(firm+1)			0.004 −0.52	0.275 (12.13)**
log(univ+1)*log(emp) *log(patent)				−0.01 −1.5
log(firm+1)*log(emp) *log(patent)				−0.019 (4.34)**
log(univ+1)*log(age) *log(patent)				0.013 −1.01
log(firm+1)*log(age) *log(patent)				−0.065 (8.67)**
Constant	3.471 (674.31)**	3.295 (602.60)**	3.470 (669.30)**	3.282 (613.47)**
Observations	101,939	86,259	101,939	86,259
Number of Group	52,799	44,643	52,799	44,643
R-squared	0.00	0.01	0.00	0.01

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

with patents that survived in both years tend to show stronger growth performance. The stronger influence of inter-firm linkages for smaller firms may be due to the fact that collaborating with other firms mitigates commercialization risks associated with patented technology. The absence of a size effect on industry-academia linkage may indicate that such activities are far from the commercialization stage; thus, the risk mitigation effect by open innovation tends to be small.

V. Discussion and conclusions

This paper presents, for the first time, the results of a comprehensive analysis of the innovation activities of the entire population of Japanese firms with the use of a linked dataset from the Establishment and Enterprise Census and the IIP Patent Database (JPO patent application data). In 2006, approximately 1.4% of approximately 4.5 million firms filed for patents, and substantial patenting activities were observed not only in the manufacturing field but also in other sectors, such as business-to-business services and finance. In addition, firm survival and growth are regressed with patenting and open innovation (measured by the joint patent application with other firms and universities). Results show that innovation activities measured by patenting are positively correlated with firm performance. Furthermore, the relationship between patenting and survival rate is strong for large firms, whereas that between patenting and firm growth is strong for small firms.

This paper uses patent application as an indicator of innovation. By applying for patents, firms can secure the fruits of their research, having cleared a certain level of technological risk. However, an economic risk remains as to whether this technological outcome will lead to an economic return. In other words, although firms that apply for numerous patents have a large technological capacity, they also have greater risks. According to the results of the regression analysis of survival probability, the number of patent applications (logarithmic) has a positive influence on the continuation of a company. This finding can reflect the effect of technological capability. Notably, Esteve-Perez, and Manez-Castillejo (2008) and Orgega-Argiles, and Moreno (2007) also used R&D as an alternative index. Their analysis results show that the positive relationship between R&D and company survival is particularly evident in the hi-tech industry. Their findings are consistent with our findings on innovation and company survival. Moreover, the analytical studies of Cockburn, and Wagner (2007) and Buddelmeyer *et al.* (2009) on patenting and survival rates are also useful. Most of these papers provide evidence for the positive relationship between innovation and company survival. However, the analyses conducted by Buddelmeyer *et al.* (2009) separated the patents and patent stock retained by a company and the patents and patent applications that a company files each year. The former showed a positive effect, whereas the latter showed a negative effect. This finding can be explained by the assumption that patent applications are a sign of high-risk investment and, being a high-risk return, patent application bears a negative effect on survival rate.

In a sense, the findings of this study generally support the argument of Buddelmeyer *et al.* (2009) that patenting involves counteracting factors of "technological superiority" and "greater commercialization risk." The results of survival regressions can be explained by the "greater commercialization risk" hypothesis, that is, small companies are more vulnerable to risks associated with patents; thus, their survival rate becomes lower. By contrast, the growth regression results indicate that the "technological superiority" effect of patenting is more clearly expressed in small firms. However, the growth regressions are conducted only on surviving firms. Therefore, further study is needed to evaluate the "technological superiority" effect after controlling for sample bias associated with growth regressions.

Another contribution of this study is examining the influence of open innovation on firm growth. Inter-firm linkage is observed to be more strongly correlated with firm growth for small firms. By applying patents with other firms, commercialization activities may be conducted jointly. In this sense, commercialization risk associated with a patent is shared between or among firms, and the risk mitigation effect may be greater for small firms. This logic is consistent with the absence of size effect for industry-academia linkage, whose activities are generally far from the commercialization stage.

A practical implication of this study is the reconfirmation of the importance of SME innovation policy. Our findings indicate that small firms face greater risks associated with patenting. A patent can considered an intermediate output in the innovation process; however, considerable risk is still associated before the innovation process is completed with the commercialization of the technology. Therefore, the government should provide support not only to R&D but also to technology commercialization activities.

Another implication is the importance of the effective use of open innovation in the process of firm growth. By networking with other firms, small firms may be able to mitigate risks associated with innovation activities. Therefore, policy instruments for SME innovation include not only direct financial support but also institutional arrangements to facilitate networking among small firms.

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