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Does patenting always help new-firm survival?*

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Abstract

This study examines the role of patenting activities in new-firm survival, using a data set of firms founded from 2003 to 2010 in the Japanese manufacturing and software sectors. In particular, we distinguish the effects of patenting activities of chief executive officers (CEOs) from those of patenting activities of firms, taking into account exit routes: bankruptcy, voluntary liquidation, and merger. It is found that firms that engaged in patenting activities after start-up are less likely to go bankrupt. It is also found that firms whose CEOs have experience in patenting activities before start-up are less likely to go bankrupt. In contrast, we provide evidence that CEOs' involvement in patenting activities after start-up are not helpful for survival. Furthermore, the results based on subsamples according to firm age show that while firms' patenting activities do not increase the probability of survival in the early years since start-up, they help new firms surviving after a certain period of time since start-up. While CEOs' pre-entry patenting activities have a significant explanatory power in reducing the probability of bankruptcy within a certain period of time since start-up, they have no longer significant effect afterwards. Further, CEOs' patenting activities after start-up increase the probability of exit through bankruptcy and voluntary liquidation especially after a certain period of time since start-up.

Keywords: New firm; patenting; chief executive officer; survival; firm age.

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1. Introduction

It is widely recognized that innovation fosters growth in the economy (e.g., Aghion and Hewitt, 1992). New firms can play an important role in driving innovation. Therefore, special attention has been paid to the importance of new firms in the economy by policy makers. Among new firms, innovative ones can particularly help boost regional development and growth through knowledge spillovers (e.g., Fritsch and Mueller, 2004; Bos and Stam, 2014). However, new firms often face a high risk, which may result from the liability of newness and smallness (e.g., Freeman et al., 1983; Carayannopoulos, 2009). It is not easy for new firms to perform well after start-up. In practice, many firms exit some years after start-up, while others can survive in markets. Understanding the post-entry performance of innovative firms is an important issue for the future direction of public policy.

Up to now, a rich stream of literature has examined firm survival as the post-entry performance of new firms (e.g., Bates, 1990; Mata and Portugal, 1994; Honjo, 2000; Esteve-Prez et al., 2004; Kato and Honjo, 2015). Among them, a number of studies have addressed the relationship between innovation and survival. However, they have yielded mixed results. While some studies found that innovative firms are more likely to fail (e.g., Buddelmeyer et al., 2010; Boyer and Blazy, 2014), others showed the opposite result (e.g., Fontana and Nesta, 2009; Wagner and Cockburn, 2010).[1] One important

[1]For a survey of empirical evidence on the relationship between innovativeness and survival, see Hyyti-

reason for this is that previous studies used data on firms at different ages. While large established firms have already accumulated resources after start-up, new firms tend to face resource constraints. Therefore, patents as a valuable asset may have different effects on firm performance. In addition, the role of chief executive officers' (CEOs) resources and experience tends to be overlooked in the literature on the innovation–survival relationship, although it is not negligible for firms during the start-up period. In practice, some of CEOs have experience in innovation before starting their businesses. Others are engaged in the innovation process after it. Analyzing the effects of patenting activities of CEOs may provide new insights into research on the relationship between innovation and survival.

This study examines the role of patenting activities in new-firm survival, using a data set of firms founded in Japan during the period 2003–2010. In particular, we distinguish the effects of patenting activities of chief executive officers (CEOs) from those of patenting activities of firms, taking into account exit routes: bankruptcy, voluntary liquidation, and merger. It is found that firms which do patenting after start-up are less likely to go bankrupt. It is also found that firms whose CEOs have experience in patenting activities before start-up are less likely to go bankrupt. In contrast, we provide evidence that CEOs' patenting after start-up is not helpful for survival. Furthermore, subsample regressions based on firm age show that while CEOs' previous experience in patenting activities

nenn et al. (2015).

have significant explanatory power in reducing the probability of bankruptcy within a certain period of time since start-up, they have no longer significant effect afterwards. Further, CEOs' patenting activities after start-up increase the probability of exit through voluntary liquidation and merger especially after a certain period of time since start-up.

The remainder of this study is organized as follows. The next section reviews theoretical and empirical backgrounds. Determinants of new-firm survival are discussed in Section 3. Section 4 describes the data and method used in the analysis. Results are shown in Section 5. The implications and limitations of this study are discussed in the final section.

2. Theoretical and empirical backgrounds

2.1. Patenting and firm survival

It is well recognized that new firms enter markets with new products or services. As argued by Schumpeter (1934), innovation enables firms to enjoy rents through temporary establishment of a monopoly. As suggested by Porter (1980), firms with innovative products may attract more customers and escape from fierce competition with rivals through product differentiation. Innovation can also ensure the competitive advantages of firms by reducing production costs, and it can strengthen the relative position of firms within industries. In addition, innovation may increase the chances of new firms surviving by providing successful niche strategies (Cefis and Marsili, 2006). The typical argument in

most studies of firm survival is that innovation is essential in survival since only those firms that have successfully innovated can establish and maintain a competitive advantage in the market (Buddelmeyer et al., 2010). In these respects, innovation increases the probability of new-firm survival.[2] In practice, some empirical studies support this observation. For example, Hall (1987) examined the effect of firm's R&D intensity on firm survival and found that it is positive and significant. Esteve-Perez et al. (2004) found that R&D-performing firms face lower failure rates than non-R&D performing ones. Cefis and Marsili (2006) also found that innovation has a positively significant effect on firm survival, using data on Dutch manufacturing firms.

However, it is well known that innovative activities are inherently risky and complicated (e.g., Buddelmeyer et al., 2010; Hyytinen et al., 2015). The returns to innovation are skewed and highly uncertain (e.g., Scherer and Harhoff, 2000; Carpenter and Petersen, 2002). Under imperfections in capital markets, R&D-intensive firms have limited access to external financing and cannot obtain the necessary R&D funding, because of credit rationing by external providers of finance (e.g., Stiglitz and Weiss, 1981; Honjo et al., 2014). In particular, new firms face more difficulties in financing their R&D projects, because they cannot expect earlier profit accumulations for financing their R&D projects. Some studies found that being innovative becomes a negative factor for the development of small and medium-sized enterprises (SMEs) (Freel, 2000; Boyer and Blazy, 2014). In

[2]For the comprehensive review of the evidence on the effects of innovation, see, for example, Rosenbusch et al. (2011).

these respects, it is not clear how innovation affects new-firm survival.

Regarding the innovation–survival relationship, a few studies examined the role of patents in firm survival. Patent information is increasingly used to analyze innovation and the innovation process, and patent statistics are increasingly used as a measure of innovation (Nagaoka et al., 2010). However, patent measure has some caveats. The value of patents are highly skewed, since many of patents are not used (Scherer and Harhoff, 2000). In addition, while patents represent new inventions, an estimate of Arundel and Kabla (1998) indicate that on average 36% of product innovations applied for patents. Therefore, many new inventions may not be applied for patents to ensure secrecy (e.g., Arundel, 2001). However, patents are important intellectual property assets that create a unique competitive advantage of firms. Patents prevent competitors from utilizing the protected inventions for a certain period, so that firms can appropriate the returns from their investment in R&D (e.g., Levin et al., 1987). Accordingly, patenting can improve firms' competitive position, which results in a higher probability of survival (Wagner and Cockburn, 2010). In this respect, firms use patenting as a strategic means in their innovation activities to ensure the competitive advantage.

In particular, patenting may play a more important role in new-firm survival. During the start-up period, firms face severe information asymmetries under imperfections in capital markets. The asymmetric information problem tends to be especially severe in high-tech sectors, because firms are reluctant to disclose their research and development

(R&D) projects (e.g., Guiso, 1998; Hall and Lerner, 2010). As suggested by Himmelberg and Petersen (1994), high-tech firms tend to be more credit-rationed than low-tech ones, partly because information asymmetries are severe and therefore adverse selection problems are pronounced especially in high-tech sectors. A number of studies argue that patents signal the quality of firms to external stakeholders in the presence of information symmetries, and that patents act as quality signals to potential lenders and investors, in particular to venture capitalists (VCs) (e.g., Audretsch et al., 2012; Conti et al., 2013; Hottenrott et al., 2016). It therefore contributes to reducing information asymmetries in entrepreneurial finance (Conti et al., 2013). As a result, firms' patenting activities significantly affect the post-entry performance of firms, such as survival.

2.2. Patenting activities by CEOs

Does patenting always help new-firm survival? Previous studies have indicated the importance of patenting in new firms. However, the role of CEOs in patenting activities tends to be neglected in the literature. Some CEOs (especially founder-CEOs) have technological experience before start-up, because they have worked as engineers in other firms or scientists in universities or public institutes. Such CEOs have superior technological knowledge and skills. It is often argued that founders' own resources are fairly valuable for new firms with limited resources (e.g., Colombo and Grilli, 2005; Okamuro et al., 2011). In practice, a number of studies found that founders' human capital plays a critical role in firm performance, because of their superior capabilities and thus better

judgment (e.g., Bates, 1990; Cressy, 1996; Colombo and Grilli, 2005; Kato et al., 2015; Kato and Honjo, 2015). In addition, founders' patents may act as a signal of firm quality to external providers of finance under information asymmetries. It is therefore considered that founders who have experience in patenting activities as representing technological experience are more likely to access external finance than those without patents, which may result in a higher probability of survival of their firms.

Meanwhile, some of CEOs who engaged in innovation activities may be still involved in the innovation process even after start-up.[3] Some previous studies examined whether top managers are directly involved in the innovation process affects firm performance. Wang and Dass (2017) argued that top managers play a central role in making strategic decisions and guiding strategic orientation in the firms. Therefore, a firm's strategic innovation orientation is likely to be determined at the top management level (e.g., Talke et al., 2011). Consequently, top managers play an important role in the innovation process. In practice, some studies, including Yadav et al. (2007), found that top managers' involvement in the innovation process improves firm performance.

However, other studies suggest that top managers should not be involved directly in the innovation process, while they have to guide and facilitate innovation activities as well

[3]According to the Patent Act in Japan, a patent application can be made for an invention by individuals as well as organizations that contributed directly to the invention. From an economic policy perspective, it is fairly important to provide firms strong incentives to invest in R&D, which enhances national innovation capacities. In the case of inventions by employees, while patent applications are usually made by their employers, reasonable remuneration has to be paid to employee inventors in exchange for the transfer of exclusive patent rights, which may reinforces inventors' motivation (e.g., Onishi, 2013).

as allocate resource and resolve conflicts (e.g., Hegarty and Hoffman, 1990). Johne and Snelson (1988) pointed out that excessive involvement by top managers delays and upsets the innovation process. Lazear (2005) argued that entrepreneurs should be jacks-of-all-trades, and they must be sufficiently good at a wide variety to make sure that the business does not fail. Especially during the start-up period, founders should possibly concentrate on managerial tasks, such as raising fund and hiring workers, rather than be involved in specialized tasks. These arguments imply that CEOs' involvement in patenting activities after start-up is not always beneficial for new firms.

While previous studies have focused on firms' innovation, the role of top managers in innovative activities has been overlooked in the literature. This study examines the role of CEOs in patenting activities before and after start-up. Taking into account top managers' patenting activities may provide new insights into the determinants of the post-entry performance of innovative firms.

3. Determinants of new-firm survival

3.1. Patenting activities

To capture new firms' patenting activities, we consider patenting activities by firms and CEOs using information on patent applications. Post-entry patenting is computed as the stock of patent applications made by a firm or a CEO. Following previous studies (e.g., Griliches and Mairesse,1984; Hottenrott et al., 2016), we compute the variables for patent

stock, using a constant depreciation rate (δ) of 15%, as follows:

$$Postpat_{i,t} = (1-\delta)Postpat_{i,t-1} + Patapp_{i,t}, \tag{1}$$

where $Postpat_{i,t}$ is firm i's patent stock in period t, $Postpat_{i,t-1}$ is firm i's patent stock in period $t-1$, and $Patapp_{i,t}$ is the number of patent applications in period t. $Postpat_{i,t}$, denoted byand $Postpat\_firm$ and $Postpat\_CEO$, indicates the stocks of patents applied after start-up by the firm or the CEO (or its successor), respectively.

The variable for pre-entry patenting is measured by a CEO's patent applications before start-up ($Prepat\_CEO$).[4] This is measured as a dummy variable indicating 1 if the CEO has experience in patent applications before start-up, 0 otherwise.

3.2. Control variables

A number of control variables are included in the model. Regarding firm-specific characteristics, we include a variable for firm age (Age_firm), which is defined as the number of years since the establishment of firms. The squared term (Age_firm^2) is also included in the model. As indicated by Evans (1987), firm survival and exit depends heavily on firm age, and firms with a longer history are likely to perform differently to newer firms because of learning after start-up. It is plausible that the probability of exit decreases

[4]There should be multiple founders in some of new firms. In this case, it is generally considered that both CEOs and their co-founders are included in the applicants for patents. Therefore, the results do not depend on whether firms have multiple founders.

with firm age because of a learning effect.

In addition, we examine the effect of firm size ($Size\_firm$), defined as paid-in capital at start-up, on new-firm survival. The squared term ($Size\_firm^2$) is also included in the model. A large number of studies have provided evidence that the probability of survival increases with firm size (e.g., Audretsch, 1991; Audretsch and Mahmood, 1991, 1995; Honjo, 2000). There appear to be some reasons that larger firms are more likely to survive than smaller ones. As pointed out by Audretsch and Mahmood (1995), larger firms may be more likely to be closer to the minimum efficient scale to operate efficiently in a market, and are therefore less likely to be vulnerable than smaller firms that operate further up the cost curve. In addition, Geroski et al. (2010) pointed out that larger firms may be more efficient than smaller firms, not because they operate a different point on the cost curve, but because they may have different managerial capabilities. That is, the size of firms may be a consequence of their capabilities.

Further, regarding CEO-specific characteristics, the CEO's age and gender are controlled in the model. Older CEOs have more experience and networks in businesses than younger ones. However, some older CEOs who are approaching retirement age and lack successors may be more likely to voluntarily close their firms even when successful. In this study, dummies for CEOs' age (the reference category is the age under 30 years old) are used. As for gender differences, several studies have examined the effect of gender of top managers on the post-entry performance of firms (e.g., Kalleberg and Leicht 1991,

Carter et al. 1997, Harada 2003). Fairlie and Robb (2009) found that female-owned businesses have lower survival rates owing to less start-up capital, and concluded that female business owners have different preferences in terms of goals for their businesses. Moreover, industry dummies at the two-digit Standard Industrial Classification (SIC) level are included in the model.

4. Data and method

4.1. Data sources

The data set employed in this paper comes from *COSMOS2*, which is compiled by Teikou Databank Ltd. (TDB), one of the major credit investigation companies in Japan. As a public data source, the *Establishment and Enterprise Census* reports data, such as numbers of entries and exits, at the individual establishment level, for individual industries or regions. However, it is difficult to obtain data for individual firms from public data sources, and generally we cannot use these sources to identify which establishment (or firm) has become active or extinct. Additionally, reliance on these sources is accompanied by the possibility that the relocation of an establishment to another region is recorded as an exit even if the establishment remains in the market. These sources thus create difficulties in identifying whether the firm actually exited the market.

The data set consists of firms in manufacturing and software sectors founded between 2003 and 2010, and includes information on the survival and exit of such firms from their

year of entry to 2013. The data provides information not only on whether a firm exits but also its exit route. Besides information on survival and exit, this source provided basic information on CEO-, firm-, and industry-level characteristics, such as the CEO's date of birth, the firm's number of employees, and industry code.

To link the above data with patent data, we employ the *IIP Patent Database* complied by the Institute of Intellectual Property. It covers all the patents that have applied to Japan Patent Office since 1964.[5] With this data base, we searched for patents applied by firms and CEOs (or successors) based on their names and addresses.

4.2. Survival and exit routes

As explained above, we classify exits into three routes—bankruptcy, voluntary liquidation, and merger—using classifications in the *COSMOS2*. Bankruptcy is the situation in which firms cannot repay their debt and thus cease operations, and includes firms that apply for court protection under the Bankruptcy Law, as well as those that apply for it under the Corporate Rehabilitation Law or the Civil Rehabilitation Law.[6] Additionally, when banks stop providing credit to service bills payable, firms are considered bankrupt even in the absence of a court judgment. That is, we here define bankruptcy to include not only firms legally declared bankrupt but also those that are inactive economically.

In contrast, voluntary liquidation indicates the situation where firms voluntarily

[5]For more details for this data base, see Goto and Motohashi (2007).

[6]Generally speaking, the Bankruptcy Law is similar to Chapter 7 in the United State while the Corporate Rehabilitation Law and the Civil Rehabilitation Law are similar to Chapter 11.

dissolve their businesses without insolvency. A number of reasons may exist for voluntary liquidation, although their precise definition can be difficult. Some entrepreneurs may dissolve their businesses because they recognize they are performing poorly and insolvency is likely. Others may voluntarily dissolve their businesses to take advantage of higher wages working elsewhere as employees. Further, other entrepreneurs may close their businesses because they are approaching retirement age and lack successors.

Finally, merger describes the situation in which a firm disappears owing to a merger with another firm.[7] Merger does not indicate business failure and is not necessarily caused by poor performance. Rather, some merged firms are likely to have superior capabilities or valuable resources since merger targets are often those firms with growth potential or valuable resources.

However, a problem arises when we identify exit route and timing, since the *COSMOS2* does not allow the identification of the date of all exits. According to the TDB, its researchers collect information on firms by telephone, postal questionnaires, and field surveys several times a year. This information is no longer updated for exited firms. Therefore, using information on the accounting period of the last statement of accounts before exit, we identify the exit year for firms. For these firms, the year following the reporting of the final statement of account is regarded as the exit year.

[7] In this paper, merged firms are regarded to have exited, but merging firms—that is, firms that absorb merged firms—are not thus regarded because they remain in the market.

4.3. Method

In this paper, the post-entry performance of new firms is classified as either survival or exit by one of three routes: bankruptcy, voluntary liquidation, and merger. Our interest is to estimate the probability of a new firm surviving (exiting) and to identify the factors that determine its exit route. However, some firms do not exit during the observation period; that is, their duration to exit is right-censored. For this reason, previous literature has applied the duration model—specifically, the proportional hazards model—to the survival and exit of new establishments or firms over time (e.g., Audretsch and Mahmood 1991, 1995; Mata et al. 1995; Honjo 2000). The duration model has an advantage, because it can accommodate right-censored observations.

In this paper, we use a discrete-time duration model to examine the factors that affect new-firm duration and how they vary according to exit route. While some previous studies have used the continuous-time duration model to examine the duration of firm survival, others have instead used the discrete-time duration model (e.g., Fontana and Nesta 2009, Cefis and Marsili 2011, 2012). Because the timings of survival and exit are observable only to the year, we use the discrete-time duration model, following Fontana and Nesta (2009) and Cefis and Marsili (2011, 2012).

As discussed above, we consider three exit routes—bankruptcy, voluntary liquidation, and merger. That is, the number of exit routes, m, is set to three ($m = 3$). Let

x_{ij} denote a vector of covariates affecting the probability of firm i exiting via route $j(=1,\ldots,m)$. To model the transition from survival to exit through bankruptcy, voluntary liquidation, or merger, we define the hazard function, $h_{ij}(t)$, which represents the conditional probability of a transition to route j in period t for surviving firm i.

Following previous studies, we use a complementary log-log model (cloglog model, hereafter) (e.g., Jenkins, 2005). The hazard function for the cloglog model can be expressed as follows:

$$h_{ij}(t) = 1 - \exp\Big\{-\exp\Big(h_{0j}(t) + x_{ij}\beta_j\Big)\Big\}, \tag{2}$$

where $h_{0j}(t)$ is the baseline function at the t th interval with spell duration, x_{ij} is a vector of covariates (some time-varying) that affect the survival and exit of new firms, and β_j denotes the parameters to be estimated.

5. Empirical results

5.1. Descriptive statistics

Table 1 shows the number of observations and exits in the sample by industry.[8] In this study, as shown in Table 1, the final sample consists of 41,080 observations (6,129 joint-stock companies).[9] Approximately 60% and 40% of firms in the sample are classified in the manufacturing and software sectors, respectively. The number of observations is the largest in the software sector (15,817), following by general machinery (4,411) and food,

[8] Appendix Table A shows life table for survival data in this study.

[9] Firms of which the number of employees at start-up is no less than 100 were dropped from the sample, in order to focus on new small-sized firms.

beverage, and feed (3,935). As shown in Table 1, among 6,129 sample firms founded from 2003 to 2010, 875 firms (about 14%) exited up to 2013.[10] Regarding exit form, the most probable way of exit is voluntary liquidation (333), following by merger (265) and bankruptcy (277).

The definitions and summary statistics of variables used in this study are presented in Table 2.[11] The mean of the variable for pre-entry patenting ($Prepat\_CEO$) is 0.068, indicating that approximately 7% of founders in the sample experienced patent applications before start-up. The means of the variable for post-entry patenting by firms ($Postpat\_firm$) and CEOs (or their successors) ($Postpat\_CEO$) are 0.081 and 0.068, respectively. The number of patent applications by firms is larger than that of CEOs. Among control variables, the mean of paid-in capital ($Size\_firm$) is 8.926 (7.6 million yen). Table 2 indicates that CEOs' ages are distributed across different generations, while most CEOs in the sample are male (96%).

5.2. Regression results

Table 3 shows the estimation results using the cloglog model. Columns (i), (ii) and (iii) of Table 3 present the estimated coefficients for bankruptcy, voluntary liquidation, and merger, respectively. Column (i) shows that the variable for post-entry patenting by

[10] The exit rate for our sample is much lower than that in some previous studies (e.g., Dunne et al., 1988; Audretsch, 1995; Bartelsman et al., 2005). One reason is that the *COSMOS2*, on which our sample is based, comes from the company register, which does not include sole proprietorships. Therefore, the sample may exclude tiny firms, which would naturally exit the market faster than others.

[11] Appendix Table B shows the correlation matrix of variables used in the analysis.

firms ($Postpat\_firm$) has a negative effect on the probability of bankruptcy ($Bank$), indicating that firms' patenting activities contribute to a higher probability of survival. However, it is not statistically significant. The variable for pre-entry patenting by CEOs ($Prepat\_CEO$) has a negative and significant effect on $Bank$. This indicates that firms whose founders experienced patenting activities prior to start-up are less likely to go bankrupt. The variable for patenting activities by CEOs after start-up ($Postpat\_CEO$) has a positive and significant effect on $Bank$, indicating that CEOs' patenting activities after start-up are harmful to new-firm survival.

Column (ii) shows the estimation results regarding the effects of patenting activities on the probability of voluntary liquidation (VOL). The variable for firms' patenting after start-up ($Postpat\_firm$) has a negative and significant effect on Vol. It indicates that firms that engaged in patenting activities after start-up are less likely to close voluntarily their firms. Regarding CEOs' patenting activities before and after start-up, the variable for pre-entry patenting ($Prepat\_CEO$) has a positive and insignificant effect on Vol. In contrast, the variable for post-entry patenting ($Postpat\_CEO$) has a positive and significant effect on VOL, indicating that CEOs' post-entry patenting is harmful to new-firm survival in the case of voluntary liquidation. The estimation results for the effects of patenting activities on the probability of exit through merger ($Merg$) are shown in column (iii) of Table 3. The variable for firms' patenting activities after start-up ($Postpat\_firm$) has a negative and significant effect on $Merg$. This indicates that patenting firms after

start-up are less likely to exit via merger than non-patenting ones. However, the variables for patenting activities by CEOs are not significant for $Merg$.

These results indicate that firms that engage in patenting activities after start-up are more likely to survive by inventing new ideas or technologies, which may enable firms to ensure their competitive advantage. In addition, CEOs' patenting experience prior to start-up is helpful for new-firm survival. On the contrary, CEOs' patenting activities after start-up may be harmful for the survival of their firms.

With respect to control variables, Table 3 shows that firm age (Age_firm) has a significantly positive effect on the probability of bankruptcy ($Bank$), while its squared term (Age_firm^2) has a significantly negative effect on it. These results indicate that the probability of bankruptcy increases and then decreases with firm age. The effects of these variables on the probabilities of voluntary liquidation (Vol) and merger ($Merg$) are overall similar to those on $Bank$. Additionally, the effects of firm size ($Size\_firm$) and its squared term ($Size\_firm^2$) on $Bank$ are significantly negative and positive, respectively. It means that a risk of business failure decreases and then rises with firm size. The effects of $Size\_firm$ and $Size\_firm^2$ on the probability of voluntary liquidation (Vol) are generally similar to those on the probability of bankruptcy ($Bank$). In contrast, firm size has an inverted U-shaped relationship with $Merg$, indicating that the probability of

exit through merger increases and then decreases with firm size.

Turning to the effects of CEOs' age and gender, Age_Found_60 among age categories has a significantly positive effect on the probability of voluntary liquidation (Vol). This result indicates that older CEOs are more likely to exit through voluntary liquidation, partly because they tend to lose an incentive to maintain their businesses and to face difficulties in finding their successors. The dummy for male CEOs ($Male$) has a positive and significant effect on the probability of exit via merger ($Merg$), indicating that firms managed by male founders are more likely to exit through merger.

5.3. Additional estimations

So far, we have examined the role of patenting on new-firm survival, taking into account firms' and CEOs' patenting activities. In this subsection, we conduct some additional analyses to ensure the robustness of our findings and to extend our analysis more for better understanding of the patenting-survival relationship. First, while we controlled for factors affecting new-firm survival other than patenting in the model, there would be unobserved heterogeneity (frailty) between firms, such as firm-specific management abilities, skills, or culture, which may affect the survival of firms. Neglecting unobserved heterogeneity (when relevant) biases the estimated-duration dependence of the hazard rate, and may attenuate the proportionate response of the hazard variation in each regressor at any survival time (e.g., Jenkins, 2005). To take into account unobserved heterogeneity, we

estimate a random-effects cloglog model using the same variables as Table 3. We also apply a likelihood-ratio (LR) test to verify whether the panel-level variance component is unimportant and whether the panel estimator is the same as the pooled estimator (cloglog). The estimation results are shown in Table 4.

As shown in columns (i)–(iii) of Table 4, the results are generally consistent with those in Table 3. According to the LR tests shown in the bottom of this table, while the panel estimator is different from the pooled estimator for bankruptcy, the panel one is not significantly different from the pooled one for voluntary liquidation and exit through merger.

Next, we extend our analysis by examining if the effects of patenting on new-firm survival depend on firm age. Some of new firms are involved in innovation activities after start-up and appropriate their ideas by patenting to improve the competitive position in the markets (Wagner and Cockburn, 2010). However, while such firms can obtain the exclusionary right to protect their inventions through patenting, they need complimentary assets and capabilities, such as marketing and distribution channels, to turn technical knowledge into commercialized products and profit from it (e.g., Teece, 1986; Tripsas, 1997). Since new firms are not initially endowed with such capabilities, it is not necessarily clear whether patenting is an effective strategy for new firms during the start-up period. In contrast, firms can develop and establish such complementary assets after start-up. In

these respects, the effects of firms' patenting may change depending on firm age.

In addition, while firms face limited resources and experience in the early years after start-up, they can learn and accumulated resources after their establishment (e.g., Jovanovic, 1982). Some previous studies suggest that the effects of founding conditions tend to be persistent over time (e.g., Mata et al., 1995; Geroski et al., 2010). However, while CEOs' own resources may be more valuable in the early stages of the firm's life cycle, they would lose their value gradually in later stages. If so, the effects of CEOs' pre-entry experience in patenting may be more prominent in the earlier stages after start-up. Up to now, there is limited evidence as to whether technological experience, such as pre-entry patenting, have different effects on new-firm survival according to firm age.

In columns (i)–(iii) of Table 5, the estimation results are shown for observations that firm age is 4 or below. The effect of firms' patenting after start-up ($Postpat\_firm$) on the probability of bankruptcy ($Bank$) is positive and insignificant. On the contrary, the variable for CEOs' patenting before start-up ($Prepat\_CEO$) has a negative and significant effect on $Bank$. It indicates that firms whose CEOs has experience in patenting before start-up have a survival advantage in the early years since start-up. The variable for post-entry patenting by CEOs ($Postpat\_CEO$) has a positive and significant effect on the probability of voluntary liquidation (VOl), indicating that CEOs' post-entry patenting

is harmful to new-firm survival in the early years since start-up.

Columns (iv)–(v) show the results for observations that firm age is more than 4. The effects of firms' patenting after start-up ($Postpat\_firm$) on exit is negative in columns (i)–(iii), although it is not significant for bankruptcy in column (i). It indicates that firms that engaged in patenting activities after a certain period of time since start-up are more likely to survive than those that did not. In contrast, the variable for CEOs' patenting experience before start-up ($Prepat\_CEO$) has no significant effect on any form of exit in Table 5. This suggests that pre-entry technological experience by CEOs is no longer effective after a certain period of time since start-up. In contrast, $Postpat\_CEO$ has a positive and significant effect on $Bank$ and Vol, suggesting that CEOs' post-entry patenting is harmful to new-firm survival especially after a certain period of time since start-up.

6. Discussions and conclusions

This study examined the role of patenting activities in new-firm survival, using a data set of firms founded from 2003 to 2010 in the Japanese manufacturing and software sectors. In particular, we distinguished the effects of patenting activities of chief executive officers (CEOs) from those of patenting activities of firms, taking into account exit routes: bankruptcy, voluntary liquidation, and merger. It is found that firms that engaged in patenting activities after start-up are less likely to go bankrupt. It is also found that

firms whose CEOs have experience in patenting activities before start-up are less likely to go bankrupt. In contrast, we provided evidence that CEOs' involvement in patenting activities after start-up are not helpful for survival. Furthermore, the results based on subsamples according to firm age showed that while firms' patenting activities do not increase the probability of survival in the early years since start-up, they help new firms surviving after a certain period of time since start-up. While CEOs' pre-entry patenting activities have a significant explanatory power in reducing the probability of bankruptcy within a certain period of time since start-up, they have no longer significant effect afterwards. Further, CEOs' patenting activities after start-up increase the probability of exit through bankruptcy and voluntary liquidation especially after a certain period of time since start-up.

However, there are a number of limitations in this study. First, we examined patent activities at the firm and CEO levels before and after start-up. While patent data is now publicly available and useful to measure innovation, all inventions are not always patented (e.g., Cohen et al., 2002). As pointed out by Nagaoka et al. (2010), there are alternative tools for appropriating rents from inventions, such as secrecy, complex design, and speedy product development. At the same time, although patent application is a proxy of knowledge capital, it does not always mean commercial success (e.g., Teece, 1986). As argued by Banbury and Mitchell (1995) and Cefis and Marsili, (2012), it may be more meaningful to take into account the type of innovation (i.e., product vs. process,

radical vs. incremental). Alternative measures would enhance our understanding.

Second, we examined new-firm survival as a measure of post-entry performance. While firm survival is a common measure of post-entry performance in the field of industrial organization (e.g., Mata and Portugal, 1994; Honjo, 2000), it would be worthwhile using alternative measures, such as growth and profitability, especially for innovative firms (e.g., Geroski and Machin, 1992; Geroski et al., 1993; Coad and Rao, 2008; Helmers and Rogers, 2011). Third, the effects of patenting activities may vary across industries with different characteristics. In fact, the frequency and importance of innovation may vary across the life cycle of an industry (e.g., Gort and Klepper, 1982; Klepper, 1996). Industry differences should be addressed in further analyses.

This study includes some policy and managerial implications. First, we explored the effects of post-entry patenting activities, distinguishing between patent applications by firms and CEOs after start-up. The findings indicate that while firms' patenting activities after start-up help new firms surviving, CEOs' involvement in the innovation process is harmful to new-firm survival as post-entry performance. These results suggest that top managers should not be directly involved in the innovation process after start-up, while they need to promote firms' patenting activities. As suggested by Johne and Snelson (1988), however, CEOs may need to provide a supportive environment for innovation as managers after start-up than to be directly involved in the innovation process as engineers or scientists. These findings are also consistent with the argument of Lazear (2005) that

entrepreneurs should be jacks-of-all-trades than specialists.

Second, we found that CEOs' experience in patenting activities before start-up affects positively the survival of new firms. Indeed, the results indicated that such technological experience decreases the probability of bankruptcy, although only 7% of founders in our sample indeed experienced patent applications before start-up. The findings imply that founders' technological knowledge and skills are inevitable for the emergence of sustainable businesses. For this purpose, providing opportunities to develop individuals' technological knowledge prior to starting businesses is of critical importance for the creation of innovative firms in the economy.

Third, our findings indicate that the effects of patenting activities vary according to firm age. The findings indicate that firms' patenting activities contribute to reducing the probability of exit after a certain period of time since start-up, although they do not affect significantly firm survival in the early years since start-up. This finding may indicate that firms' complimentary assets other than the patent in question are required to turn the new invention into profits, which takes some time since start-up. On the contrary, the effects of CEOs' patenting activities after start-up on exit via bankruptcy and voluntary liquidation are significantly positive after a certain period of time since start-up, and they are more prominent than in the early years. Further, it is found that while CEOs' experience in patenting activities before start-up plays an important role in reducing the probability of bankruptcy in the early years since start-up, they do not help

new firms surviving after a certain period of time since start-up. These results suggest that top managers should recognize their roles in each stage.

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Table 1: The numbers of observations and exits in the sample by industry.

Industry	N of firms (A)	N of obs.	Pooled exit (B)	Exit form			(B/A) (%)
				Bankruptcy	Voluntary	Mmerger	
Food, beverage, and feed	612	3,935	87	28	34	25	14.2
Textiles	49	314	8	1	3	4	16.3
Apparel	126	791	14	4	6	4	11.1
Lumber and wood products	89	599	11	5	2	4	12.4
Furniture and fixtures	71	456	10	3	4	3	14.1
Pulp, paper, and paper products	48	334	4	0	1	3	8.3
Publishing and printing	301	1,920	52	18	17	17	17.3
Chemicals	148	954	27	4	8	15	18.2
Petroleum and coal products	15	96	5	1	3	1	33.3
Rubber products	44	290	2	1	0	1	4.5
Leather, leather products, and fur skins	37	236	4	4	0	0	10.8
Ceramic, stone, and clay products	167	1,143	28	5	10	13	16.8
Steel and non-ferrous metals	102	682	18	4	3	11	17.6
Fabricated metals	366	2,391	39	11	18	10	10.7
General machinery	661	4,411	89	31	32	26	13.5
Electrical machinery	374	2,535	61	21	27	13	16.3
Transportation machinery	121	797	14	5	6	3	11.6
Precision machinery	105	706	16	10	4	2	15.2
Miscellaneous manufacturing	408	2,673	59	18	24	17	14.5
Software	2,285	15,817	327	91	131	105	14.3
Total	6,129	41,080	875	265	333	277	14.3

Note: N indicates the number of observations. Bankruptcy, Voluntary, and Merger mean exit via bankruptcy, voluntary liquidation, and merger, respectively.

Table 2: Definitions and summary statistics of variables.

Variable	Definition	Mean	S.D.
(Dependent variable)			
$Bank$	Dummy variable: 1 if the firms exit via bankruptcy in period t, 0 otherwise.	0.006	0.080
Vol	Dummy variable: 1 if the firms exit via voluntary liquidation in period t, 0 otherwise.	0.008	0.090
$Merg$	Dummy variable: 1 if the firms exit via merger in period t, 0 otherwise.	0.007	0.082
(Independent variable)			
$Postpat\_firm$	The firm's patent stock in period t: (1 - 0.15) multiplied by the value of patent stocks in period $t-1$, plus the number of patent applications in period t.	0.081	0.359
$Prepat\_CEO$	Dummy variable: 1 if the founder has experience in patent application before start-up, 0 otherwise.	0.068	0.251
$Postpat\_CEO$	The CEO's patent stock in period t: (1 - 0.15) multiplied by the value of patent stocks in period $t-1$, plus the number of patent applications in period t.	0.068	0.252
Age_firm	Logarithm of the years after the establishment of the firm in period t.	1.230	0.676
Age_firm^2	$Age\_firm \times Age\_firm$	1.969	1.497
$Size\_firm$	Logarithm of paid-in capital of the firm (thousand yen) at start-up.	8.926	1.572
$Size\_firm^2$	$Size\_firm \times Size\_firm$	82.143	27.435
Age_Found_30	Dummy variable: 1 if the founder's age at start-up is 30 to 39, 0 otherwise.	0.200	0.400
Age_Found_40	Dummy variable: 1 if the founder's age at start-up is 40 to 49, 0 otherwise.	0.244	0.430
Age_Found_50	Dummy variable: 1 if the founder's age at start-up is 50 to 59, 0 otherwise.	0.254	0.435
Age_Found_60	Dummy variable: 1 if the founder's age at start-up is 60 and older, 0 otherwise.	0.255	0.436
$Male$	Dummy variable: 1 if the founder is male, 0 otherwise.	0.956	0.205

Table 3: Estimation results using the clog-log model.

Variable	(i) $Bank$	(ii) Vol	(iii) $Merg$
(Variables for patenting)			
$Postpat\_firm$	-0.157	-0.439**	-0.342*
	(0.155)	(0.179)	(0.189)
$Prepat\_CEO$	-0.734**	0.168	0.105
	(0.310)	(0.209)	(0.213)
$Postpat\_CEO$	0.529***	0.525***	-0.325
	(0.204)	(0.176)	(0.278)
(Control variables)			
Age_firm	3.617***	3.203***	2.622***
	(0.609)	(0.431)	(0.457)
Age_firm^2	-1.171***	-1.305***	-0.908***
	(0.220)	(0.174)	(0.175)
$Size\_firm$	-0.469***	-0.528***	1.947***
	(0.120)	(0.100)	(0.469)
$Size\_firm^2$	0.032***	0.036***	-0.068***
	(0.007)	(0.006)	(0.022)
Age_found_30	0.128	-0.014	-0.176
	(0.387)	(0.335)	(0.423)
Age_found_40	0.441	0.203	0.361
	(0.375)	(0.326)	(0.400)
Age_found_50	0.542	0.103	0.381
	(0.378)	(0.333)	(0.402)
Age_found_60	0.106	0.801**	0.670*
	(0.387)	(0.321)	(0.401)
$Male$	0.056	0.150	1.110*
	(0.326)	(0.286)	(0.583)
Constant term	-6.327***	-5.159***	-20.23***
	(0.850)	(0.682)	(2.538)
Industry dummies	Yes	Yes	Yes
Observations	41,080	41,080	41,080
Nonzero outcomes	265	333	277
Log likelihood	-1531.662	-1849.090	-1512.544

Notes: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4: Estimation results using the random-effects cloglog model.

Variable	(i) *Bank*	(ii) *Vol*	(iii) *Merg*
(Variables for patenting)			
Postpat_firm	-0.167	-0.451**	-0.342*
	(0.238)	(0.188)	(0.189)
Prepat_CEO	-1.092**	0.197	0.105
	(0.448)	(0.225)	(0.213)
Postpat_CEO	0.724**	0.544***	-0.325
	(0.304)	(0.192)	(0.278)
(Control variables)			
Age_firm	4.170***	3.206***	2.622***
	(0.720)	(0.432)	(0.457)
Age_firm^2	-1.099***	-1.285***	-0.908***
	(0.240)	(0.179)	(0.175)
Size_firm	-0.745***	-0.566***	1.947***
	(0.210)	(0.134)	(0.469)
$Size\_firm^2$	0.0513***	0.0378***	-0.0681***
	(0.013)	(0.008)	(0.022)
Age_found_30	0.257	-0.028	-0.176
	(0.542)	(0.344)	(0.423)
Age_found_40	0.740	0.205	0.361
	(0.533)	(0.334)	(0.400)
Age_found_50	0.844	0.104	0.381
	(0.538)	(0.341)	(0.402)
Age_found_60	0.248	0.834**	0.670*
	(0.542)	(0.337)	(0.401)
Male	0.028	0.154	1.110*
	(0.453)	(0.295)	(0.583)
Constant term	-9.137***	-5.428***	-20.23***
	(1.430)	(0.865)	(2.538)
Industry dummies	Yes	Yes	Yes
Number of observations	41,080	41,080	41,080
Number of firms	6,129	6,129	6,129
σ_u	2.594	0.878	0.005
	(0.295)	(0.789)	(1.103)
ρ	0.804	0.319	0.000
	(0.036)	(0.390)	(0.007)
LR test of ρ=0	3.29**	0.300	0.000
Log likelihood	-1530.018	-1848.938	-1510.564

Notes: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5: Estimation results using the cloglog model for subsamples based on firm age.

	Firm age $\leq$ 4 years			Firm age $>$ 4 years		
Variable	(i) *Bank*	(ii) *Vol*	(iii) *Merg*	(iv) *Bank*	(v) *Vol*	(vi) *Merg*
(Variables for patenting)						
Postpat_firm	0.074	-0.221	-0.134	-0.279	-0.733***	-0.553**
	(0.230)	(0.234)	(0.256)	(0.210)	(0.278)	(0.281)
Prepat_CEO	-1.036*	0.339	0.044	-0.539	-0.159	0.218
	(0.532)	(0.258)	(0.301)	(0.391)	(0.361)	(0.302)
Postpat_CEO	0.207	0.449*	-0.126	0.688***	0.647**	-0.574
	(0.376)	(0.245)	(0.361)	(0.243)	(0.256)	(0.444)
(Control variables)						
Age_firm	4.735***	2.055***	2.009***	8.252	10.340	-5.585
	(1.288)	(0.638)	(0.771)	(7.854)	(9.690)	(7.689)
Age_firm^2	-1.809***	-0.521	-0.443	-2.334	-3.285	1.304
	(0.673)	(0.381)	(0.459)	(2.080)	(2.612)	(2.022)
Size_firm	-0.531***	-0.380***	2.269***	-0.373*	-0.732***	1.660**
	(0.154)	(0.139)	(0.647)	(0.192)	(0.152)	(0.681)
$Size\_firm^2$	0.0365***	0.0235***	-0.0870***	0.0257**	0.0529***	-0.051
	(0.009)	(0.008)	(0.031)	(0.011)	(0.009)	(0.032)
Age_found_30	0.579	-0.260	-0.029	-0.085	0.294	-0.317
	(0.751)	(0.432)	(0.641)	(0.455)	(0.540)	(0.564)
Age_found_40	1.247*	0.302	0.549	-0.093	0.011	0.174
	(0.728)	(0.407)	(0.606)	(0.449)	(0.546)	(0.534)
Age_found_50	1.179	0.140	0.678	0.159	-0.021	0.042
	(0.734)	(0.418)	(0.608)	(0.448)	(0.552)	(0.540)
Age_found_60	0.856	0.871**	1.056*	-0.396	0.614	0.186
	(0.738)	(0.399)	(0.601)	(0.471)	(0.540)	(0.545)
Male	-0.145	0.180	1.599	0.279	0.131	0.729
	(0.424)	(0.345)	(1.006)	(0.513)	(0.514)	(0.717)
Constant term	-7.395***	-5.440***	-22.44***	-11.140	-11.520	-11.210
	(1.258)	(0.864)	(3.512)	(7.433)	(8.969)	(8.139)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	24,066	24,066	24,066	17,014	17,014	17,014
Nonzero outcomes	126	213	148	139	120	129
Log likelihood	-734.145	-1154.188	-798.589	-788.251	-678.160	-696.798

Notes: Standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Appendix

Table A: Life table for survival data.

Interval	N at risk	Bankruptcy	Voluntary liquidation	Exit via merger	Survival rate
0-1	6129	3	15	11	0.995
1-2	6100	23	40	23	0.981
2-3	6014	53	78	60	0.950
3-4	5823	47	80	54	0.920
4-5	5273	42	53	45	0.893
5-6	4247	46	29	30	0.868
6-7	3110	21	22	22	0.847
7-8	2206	18	12	18	0.824
8-9	1348	6	4	6	0.812
9-10	830	6	0	8	0.780

Table B: Correlation matrix of variables (Number of observations is 41080).

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) $Bank$	1.000														
(2) Vol	-0.007	1.000													
(3) $Merg$	-0.007	-0.007	1.000												
(4) $Postpat\_firm$	0.011	-0.001	0.001	1.000											
(5) $Prepat\_CEO$	-0.006	0.010	0.011	0.159	1.000										
(6) $postpat\_CEO$	0.016	0.015	-0.003	0.461	0.327	1.000									
(7) Age_firm	0.031	0.012	0.024	0.105	0.011	0.085	1.000								
(8) Age_firm^2	0.024	-0.001	0.017	0.109	0.014	0.084	0.953	1.000							
(9) $Size\_firm$	0.013	0.010	0.067	0.193	0.121	0.094	0.074	0.094	1.000						
(10) $Size\_firm^2$	0.017	0.015	0.072	0.225	0.129	0.104	0.072	0.091	0.979	1.000					
(11) Age_found_30	-0.008	-0.013	-0.020	-0.040	-0.077	-0.034	0.020	0.022	-0.087	-0.090	1.000				
(12) Age_found_40	0.006	-0.006	-0.001	-0.009	-0.038	-0.010	0.005	0.006	-0.009	-0.013	-0.284	1.000			
(13) Age_found_50	0.015	-0.010	0.008	0.055	0.088	0.052	0.029	0.036	0.125	0.130	-0.292	-0.331	1.000		
(14) Age_found_60	-0.010	0.031	0.016	0.004	0.042	0.004	-0.057	-0.067	-0.003	-0.001	-0.293	-0.333	-0.341	1.000	
(15) $Male$	0.002	0.002	0.013	0.038	0.029	0.035	0.013	0.017	0.091	0.090	0.006	0.013	0.028	-0.046	1.000