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Venture Capital and Startup Innovation
—Big Data Analysis of Patent Data—

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Abstract

With the declining birthrate and ageing population and a decline in the working age population in Japan, Japanese firms face the need to strengthen innovation including the digital domain. Expectations are particularly high for startups as they play a vital role in creating innovative technology. In recent years, there have been a number of initiatives such as expediting patent examinations and introducing an open innovation tax incentive in Japan. It is expected that venture capital (VC) funds will play a pivotal role in providing financing for growth so that startups can continue research and development. On the other hand, due in part to data constraints, there has been limited research on startup innovation on a comprehensive scale and virtually no earlier literature on the impact of VC investments on innovation by portfolio companies in Japan. This paper summarizes those two issues with a focus on the number of patent applications as a proxy for innovation, and it also discusses challenges that lie ahead.

First, taking a look at patent applications by startups, around 40 percent of startups have applied for a patent—albeit with significant variation across firms—which appears a much higher proportion than existing firms. An estimate of the impact of VC investments on innovation suggests that in about 60 percent of cases, the number of patent applications by portfolio companies significantly increased compared to a control group. While care should be taken in interpreting those studies as the results vary from firm to firm, these successful cases reflect the possibility that financing and management support including intellectual property management from VC funds could have contributed to an

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increase in patent applications. Challenges ahead include: (1) expanding investments in VC funds by institutional investors; (2) increasing opportunities for startups to go public in a way that encourages sustainable growth; and (3) establishing intellectual property strategies while maintaining and developing professional human resources in relevant areas.

1. Introduction

As the working age population in Japan has decreased since the mid-1990s after the burst of the bubble economy, the importance of innovation has increased in the context of productivity gains and economic growth. It is also expected digitalization coupled with a review of optimum business models will progress in various industries following the COVID-19 crisis, which will require further strengthening of innovation. Expectations are particularly high for startups as they play a vital role in creating innovative technology. In recent years, the patent examination period has been shortened[1] and a tax incentive for open innovation—where existing firms and startups collaborate—has been introduced. Venture capital (VC) funds are expected to have a pivotal role in providing financing for growth so that startups can continue research and development (R&D). On the other hand, due in part to data constraints, there has been limited research on startup innovation on a comprehensive scale and, as far as the author knows, there is virtually no earlier literature on the impact of VC investments on innovation by portfolio companies in Japan. This paper summarizes those two issues with a focus on the number of patent applications as a proxy for innovation and discusses the challenges that lie ahead.

This paper is structured as follows: Section 2 outlines stylized facts on startup innovation; Section 3 explains the role of VC funds in innovation; Section 4 presents challenges ahead; and Section 5 concludes with key takeaways.

2. Stylized Facts on Startup Innovation

R&D investment and the number of patent applications or citations are used as typical indicators to measure innovation. However, there has been limited comprehensive research on startup innovation in Japan[2] due in part to the difficulty in giving an objective

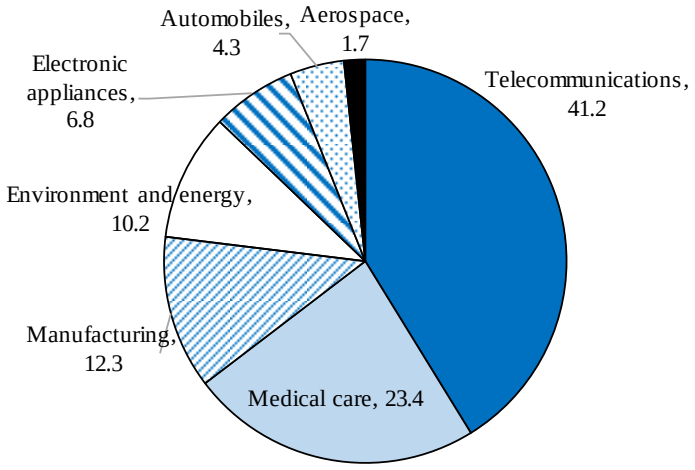
[1] The average patent examination period was shortened by 4.5 months between FY 2013 and FY 2019 (18.8 months to 14.3 months), and a super-accelerated examination for startups was introduced in July 2018, which could take as little as around 2.5 months.

[2] For instance, regarding specific industries, the Japan Patent Office published a report in 2020 on patent applications by biotech startups and Motohoshi (2011) measured firms' patent registration rate by the number of employees and the year of establishment using the Enterprise Census and the IIP patent database.

definition of startups (e.g., a clear distinction from SMEs) and limited disclosure of financial data. This paper provides an overview of patent applications by unlisted firms that are registered in "STARTUP DB"—a database that focuses on the growth sector. With respect to patent data, this paper uses the IIP patent database (2020), which is provided by the Institute of Intellectual Property.[3]

According to STARTUP DB, startups are defined as "firms that target an exit by achieving drastic growth in the short term with fundraising while creating new businesses through innovation."[4] Given that having a new business and innovative technology are essential elements to be defined as a startup, very few SMEs and firms with a relatively short history fall into that category. More than ten thousand firms including listed firms are registered in STARTUP DB, so this paper focuses on (1) unlisted firms that were established between 2000 and 2012 and (2) business sectors[5] including manufacturing, automobiles, electric appliances, aerospace, environment and energy, medical care, and telecommunications (Figure 1).

Figure 1: Startup Profiles Subject to Analysis



Note: Based on STARTUP DB. The sample includes 529 startups.

[3] The analysis in this paper conducts name-based aggregation because the names and addresses of startup firms might have changed over time.

[4] In this respect, *venture kigyo* is Japanese-English and it often represents firms that tackle challenges over a longer horizon relative to startups.

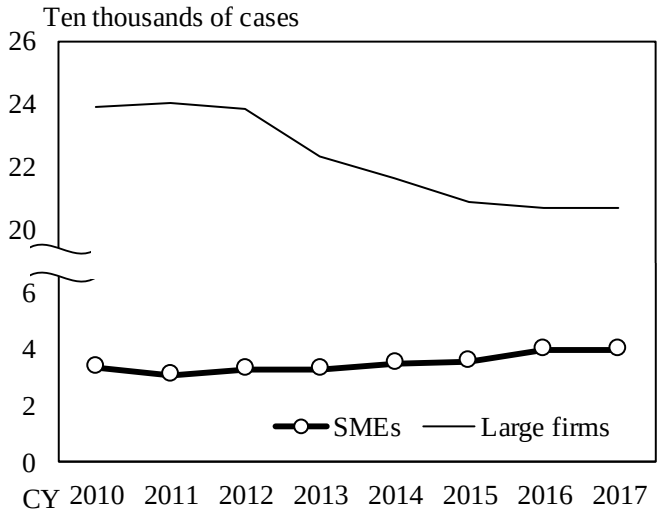
[5] It should be noted that this category is different from industry classification and some startups fall into several categories.

Earlier literature pointed out several caveats in using patent data as a proxy for innovation. First, it should be noted that applications are not made for all patentable inventions. Second, according to Kimura (2018), there is a greater heterogeneity in the quality of inventions as some patents generate a significant economic value while others do not. One option to deal with that issue could be to use the number of times a patent has been cited by other patents, but the number of citations might not increase in niche areas even if the technology itself is innovative. Furthermore, Oh and Takahashi (2020) shows that the average period for citation after patent registration ranges from two to five years, indicating a considerable lag in measuring innovation. Given those points, this paper uses the patent application numbers as a proxy for innovation.

Looking at the trend of patent applications by Japanese firms to grasp the big picture, the number of patent applications by SMEs has increased moderately while applications by large firms have plateaued (Figure 2). While the data is somewhat outdated, the patent application rate based on the number of employees shows that the rate of companies that have less than 100 employees is below 10 percent (Figure 3). On the other hand, the patent application rate of startups from their establishment to 2018 is around 40 percent, which is far higher than existing firms (Figure 4). This indicates that startups have been actively involved in the innovation process. That said, the distribution of cumulative patent applications by startups has a very long tail, suggesting that some startups account for a substantial number of patent applications (Figure 5).[6]

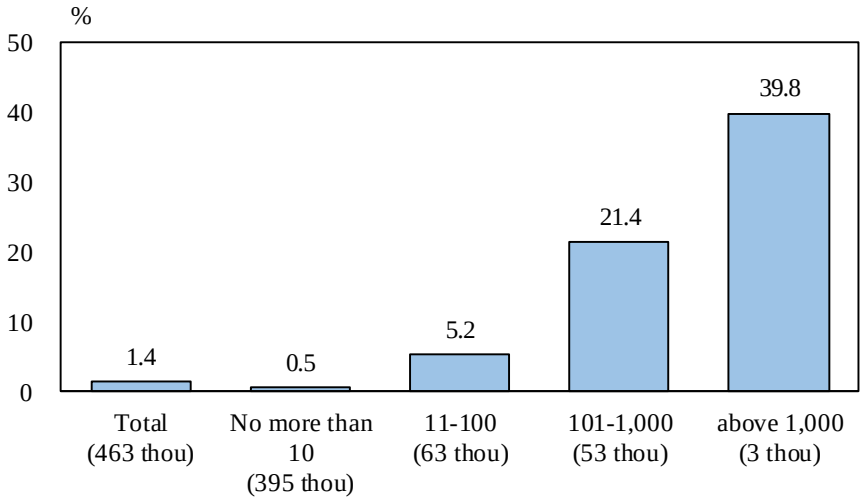
[6] According to Kimura (2018), these characteristics can be also observed in Japanese firms in general, and the distribution of patent applications during a one-year period has a long tail.

Figure 2: Number of Patent Applications by Firm Size



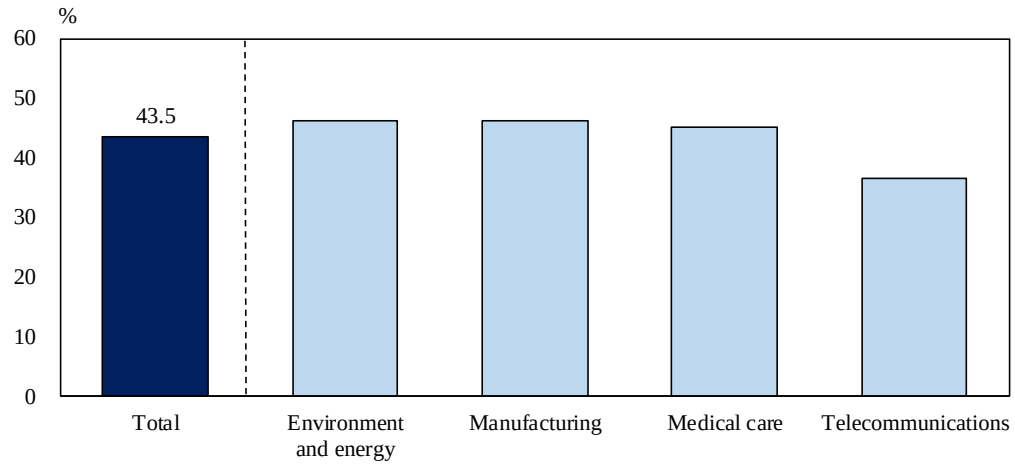
Source: Japan Patent Office "Fundamental Survey for Intellectual Property Activity of SMEs"

Figure 3: Patent Application Rate by Number of Employees (2006)



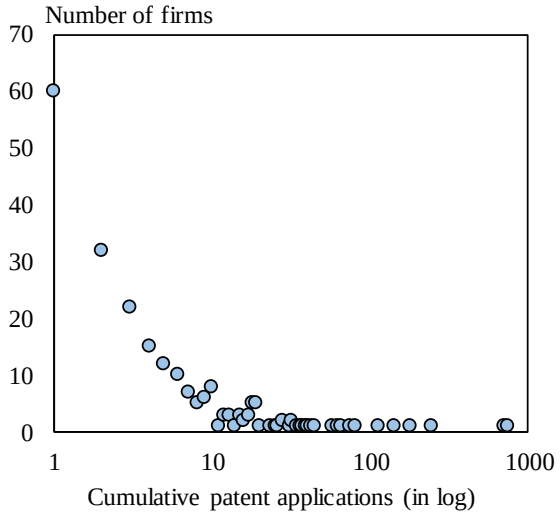
Note: Based on Motohashi (2011). The numbers in parenthesis are sample sizes.

Figure 4: Patent Application Rate of Startups



Note: Based on STARTUP DB and IIP Patent Database (2020).
Counts patent applications up to CY 2018. Sector breakdowns for the sample size of more than 100 firms.

Figure 5: Distribution of Cumulative Patent Applications by Startups



Note: Based on STARTUP DB and IIP Patent Database (2020).
Counts patent applications up to CY 2018.

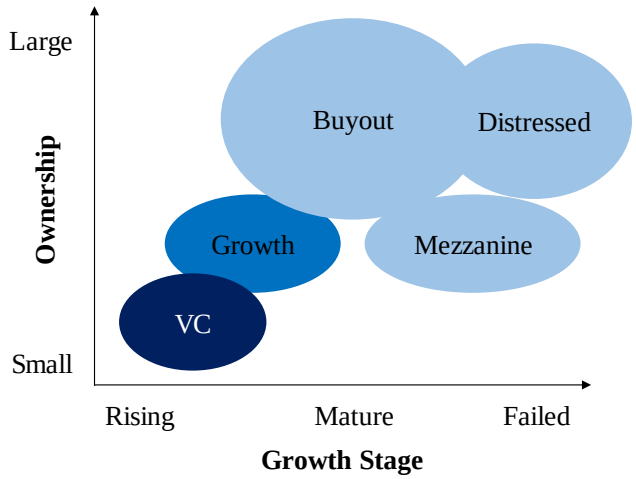
3. Impact of VC Investments on Innovation by Portfolio Companies

The previous section suggests that the patent application rate of startups is far higher than existing firms. Since sustainable R&D investments are necessary to create those innovations, VC funds have gained attention as the main source for growth financing. This section summarizes the role of VC investments in innovation and provides an

empirical analysis of the impact of VC investments on the number of patent applications by portfolio companies.

In general, funds that invest in unlisted shares are classified as private equity funds (PE funds). Nevertheless, there are various types of funds depending on the growth stages of the portfolio companies (Figure 6). For instance, venture capital funds invest in startups (from seed to early stage), growth capital funds support the expansion of startups (from middle to later stage), and buyout funds mainly target more mature unlisted firms.[7]

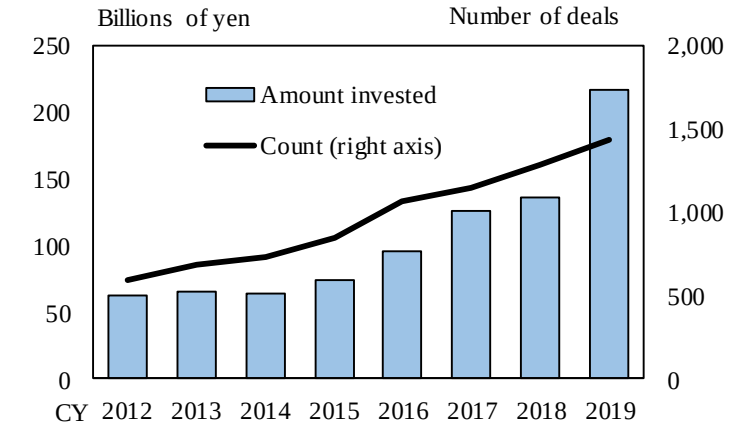
Figure 6: Investment Strategy by Funds



VC funds usually acquire less than a majority of shares and expect a return by the sale of shares through an IPO or M&A, while providing management support and increasing the added value of their portfolio companies. Management support includes not only developing sales channels and introducing human resources, but also giving advice on intellectual property strategies and connecting portfolio companies to expert networks in relation to innovation. The size of Japan's VC market remains smaller than other major countries such as the U.S. and China, but investments by VC funds in Japan have picked up in recent years (Figures 7 and 8).

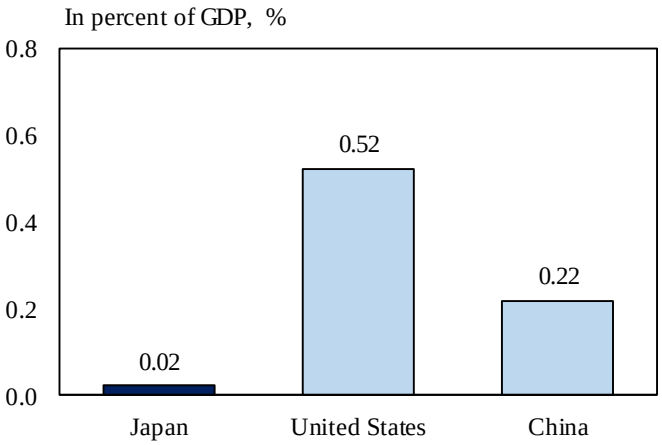
[7] This paper focuses on VC funds including growth capital funds. For the role of PE funds (in particular buyout funds) in corporate restructuring and their economic impact on portfolio companies, see Washimi (2020).

Figure 7: Domestic Investments by VC Funds



Source: Venture Enterprise Center

Figure 8: Size of VC Market in Japan Compared to Other Countries (CY 2016-18 average)



Source: Venture Enterprise Center, PitchBook, IMF

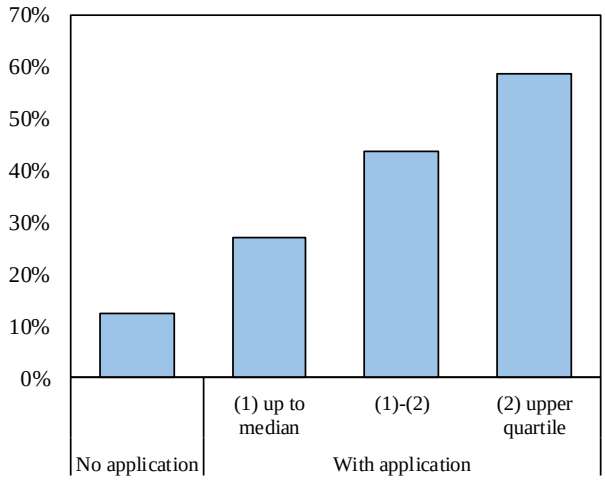
Meanwhile, empirical works on the impact of VC investments in Japan have been very limited relative to other countries due in part to data constraints. Having said that, Ishii (2011), for instance, shows that portfolio companies of funds backed by SME SUPPORT JAPAN attained higher growth in sales and the number of workers than a control group with similar characteristics. Morioka (2016) applied a propensity score matching[8] to borrowers of Japan Finance Corporation and found that there is a significant

[8] The study conducted matching based on a propensity score that summarizes financial metrics such as ROA and capital adequacy ratio.

difference in growth in sales and the number of workers between the treatment group (portfolio companies of VC funds that aim to develop SMEs) and a control group.[9] Nevertheless, as far as the author knows, there has been virtually no empirical work on the impact of VC investments on innovation by portfolio companies in Japan.[10]

There appears to be a positive association between the number of patent applications by startups and financing from VC funds (Figure 9). However, the question of whether that stems from the fact that VC funds have paid attention to the number of patent applications in selecting investment targets or investments by VC funds have contributed to the outcome of R&D in portfolio companies remains open. This paper therefore aims to examine the impact of VC investments while reducing any sample selection bias by making a comparison with control firms that have similar characteristics. The synthetic control method using a Bayesian structural time series model has been employed in order to reduce arbitrariness in matching (see the Appendix for details).

Figure 9: Ratio of Startups Receiving Funding from VC Funds



Note: Based on STARTUP DB and IIP Patent Database (2020). Counts patent applications up to CY 2018. The sub-categories within "with application" are based on quantiles of the number of applications.

[9] As both Ishii (2011) and Morioka (2016) mentioned, there could be a bias in samples. It should also be noted that the control groups did not necessarily consist of startups.

[10] Among previous works in other countries, Akcigit et al. (2019), for instance, conducted matching with control groups that have similar characteristics and showed that the patent citations of VC-backed startups increased after the initial funding from VC funds. Bertoni et al. (2010) pointed out that the number of patents granted to VC-backed startups (high-tech sector in Italy) significantly increased after the funding from VC funds.

The results suggest that the number of patent applications by portfolio companies significantly increased since the first year of VC funding compared to a control group in about 60 percent of cases (Figure 10).[11] These successful cases reflect the possibility that financing and management support including intellectual property management from VC funds could have contributed to an increase in patent applications, albeit with variation across firms.[12] In fact, various surveys[13] including interviews suggest that VC funds have assisted in finding license partners and provided advice on intellectual property strategies.

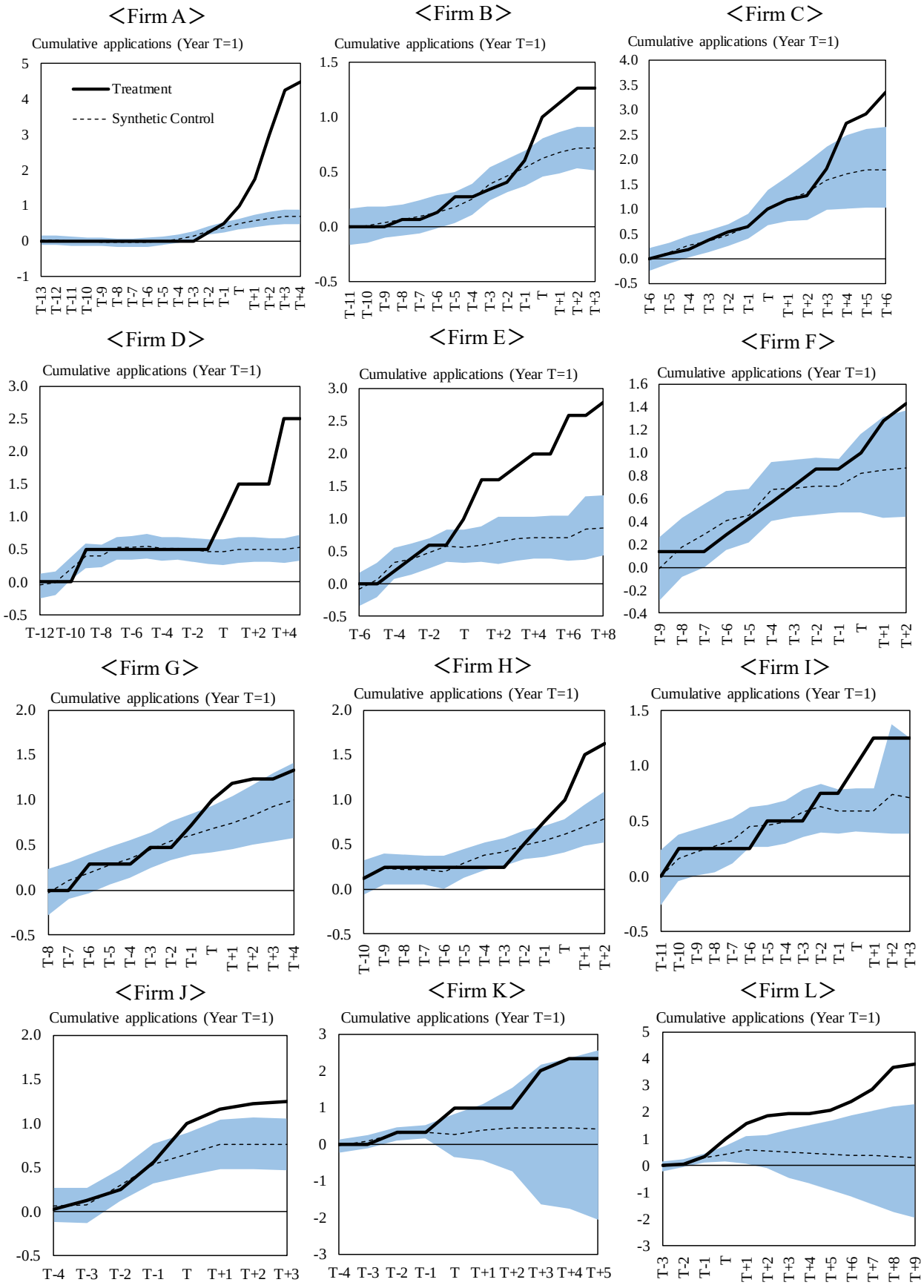
The empirical analysis in this paper could not assess the impact of VC investments by VC type due to limited sample sizes. However, previous literature in other countries (Akcigit et al. (2019)) reveals that extensive experience of VC funds could make a difference to the impact on innovation of portfolio companies. In other words, the experience of VC funds in management knowhow and intellectual property strategies could have a vital role in enhancing innovation.

[11] The number of patent applications by VC-backed startups significantly increased since the initial funding from VC funds relative to synthetic controls for 15 firms (Firms A-O) out of 24 samples. On the other hand, regarding the remaining 9 firms (Firms P-X), the number of patent applications by VC-backed startups increased albeit not at a significant level or stayed more or less the same as the synthetic controls.

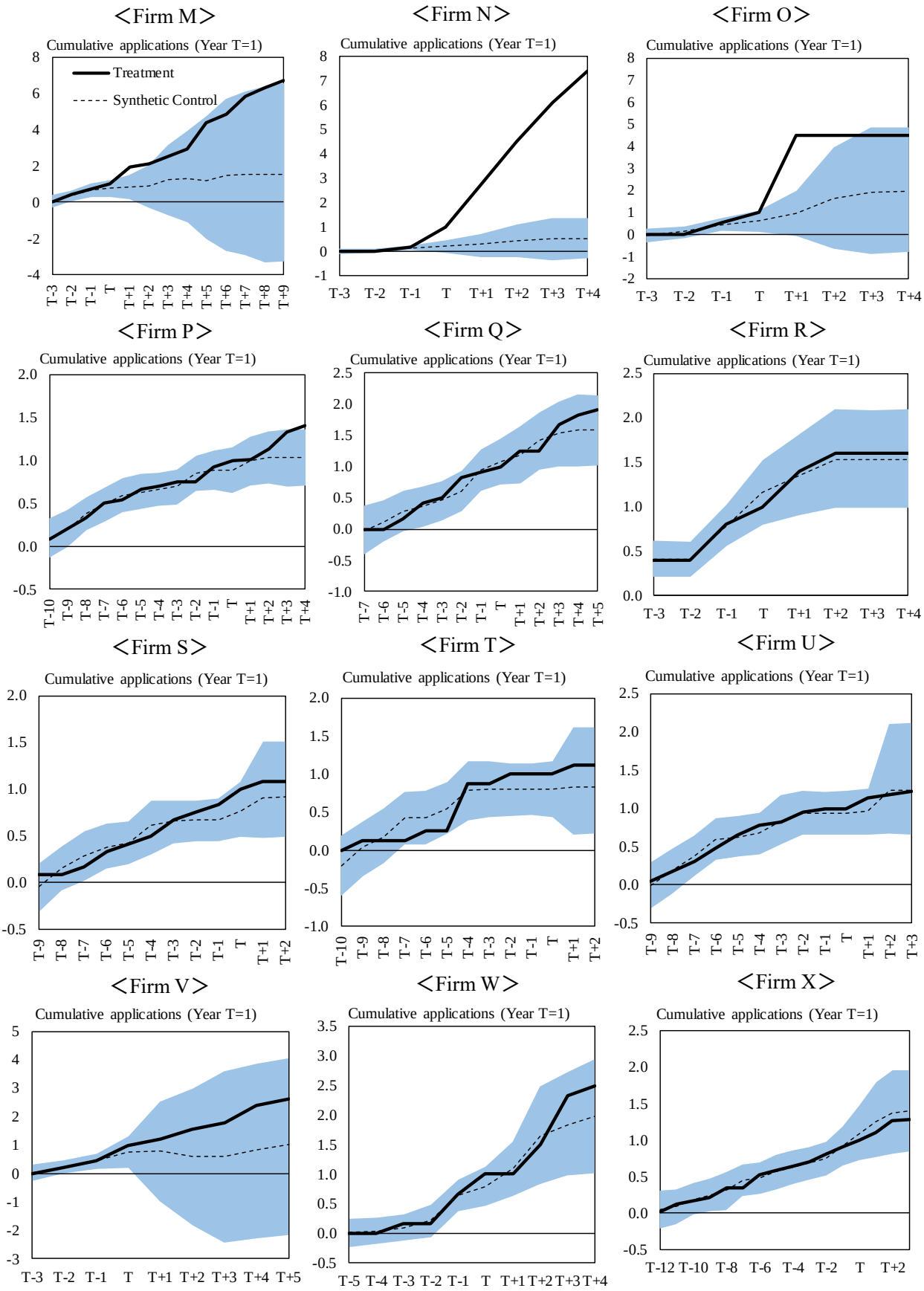
[12] While a chi-squared test is conducted to check the possibility of reverse causality between the change in the number of patent applications (lagged) and funding from VC funds, there is no statistically significant relationship between them. Another point to be noted is the possibility of measurement errors in the timing of funding from VC funds as some information on funding sources is missing for some startups.

[13] Regarding the questionnaire survey, see, for example, the Report on Intellectual Property Challenges that Startups Face and How the Support Should Be (2018) (*Japanese only*) published by the Japan Patent Office.

Figure 10: Impact of VC Investments on Number of Patent Applications by Portfolio Companies



Note: Year T corresponds to the initial VC funding. The shaded areas represent 90 percent confidence intervals.



Note: Year T corresponds to the initial VC funding. The shaded areas represent 90 percent confidence intervals.

4. Challenges Ahead

If VC investments are to have a positive impact on innovation as a whole as discussed in Section 3, expanding those investments could lead to an acceleration of a favorable cycle of the ecosystem through the spread of continuous growth funds for startups. To expand the size of VC investments and enhance startup innovation, at least the following three challenges need to be addressed.[14]

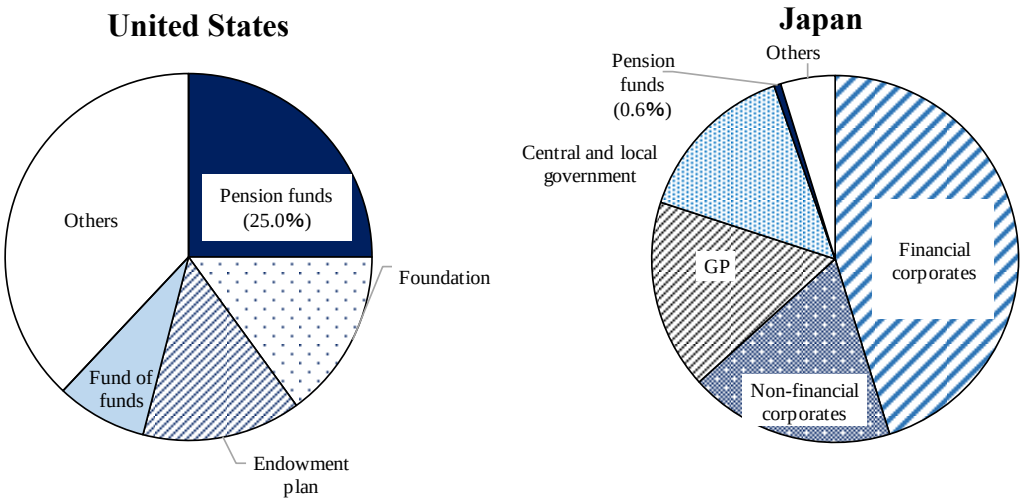
First, institutional investors could further increase investments in VC in Japan. For instance, while pension funds account for about a quarter of VC investments in the U.S., they comprise less than one percent of VC investments in Japan (Figure 11). Institutional investors are medium to long-term investors and play a crucial role in financing for sustainable R&D and growth. In terms of performance, given that the net internal rate of return (IRR)[15] for domestic VC funds is greater than 15 percent, increasing VC investments could be worth considering as alternative investments in Japan. As discussed in previous literature,[16] institutional investors seek consistency in accounting standards on mark-to-market valuation together with a shift to fair value based valuation with respect to VC investments. It is therefore expected initiatives on fair value based valuation across funds—including the above performance benchmarks—will progress.

[14] As Aoki (2001) discussed from a comparative institutional analysis perspective, firm organizations and their surroundings interplay with each other in a complicated manner in terms of institutional comparisons at the international level. Differences in competition policy can also have an effect, as Porter and Sakakibara (2004) has noted. Among others, this section focuses on key issues raised by industry representatives and others.

[15] Based on net IRR (with vintage years between 2010 and 2014) from the Second Performance Benchmark Update for Japanese Venture Capital (December 2020) by Preqin and the Japan Venture Capital Association.

[16] For instance, see Fundamental Survey for Effective Use of Funds That Have a Role in Revitalizing the Japanese Economy (*Japanese only*) published by the Ministry of Economy, Trade and Industry (March 2011).

Figure 11: Breakdown of VC Investments by Investor Type



Note: The chart for VC investments in the U.S. is based on the Overview of the U.S. Venture Capital Industry December 2015 published by Preqin, while that the chart for Japan is based on the White Paper on Venture Capital 2016.

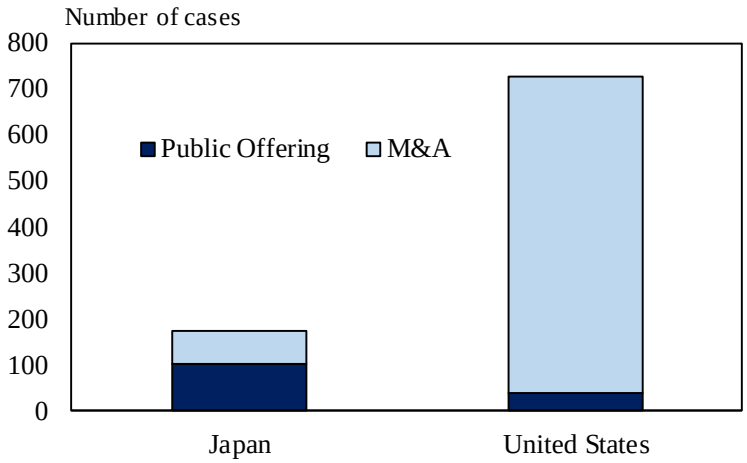
Second, opportunities to go public must increase in a way that allows startups to achieve sustainable growth. Currently, IPOs in emerging markets are the main exit route for VC-backed startups in Japan (Figure 12),[17] and individual investors account for a majority of the investors in emerging markets.[18] For startups to achieve sustainable growth, as stronger governance is required from VC funds before an IPO, management discipline suitable for a business model is crucial so that startups can aim at not only short-term profitability but also at medium-term investment for growth after an IPO. In this regard, it has been acknowledged that the participation of institutional investors is needed and it is expected the criteria on the number of shareholders and distributions to investors at the time of an IPO are to be reviewed. At the same time, it would be desirable if startups that require upfront investments and need a long period for R&D can obtain financing by showing that their business plans for the future are rational, even if they are initially unprofitable. In this connection, it has been pointed out that non-financial information (e.g., efficacy of trial products, patent details, etc.) has become particularly

[17] IPOs are more favorable in emerging markets in Japan than in other countries because the entry barrier is lower and a wide variety of startups can be listed and accounting for goodwill can act as a bottleneck for the buyers in M&As.

[18] For instance, according to a 2018 study on the optimum management integration between large firms and startups by the Ministry of Economy, Trade, and Industry, the average ratio of distribution to individual investors is around 75 percent for IPOs on Tokyo Stock Exchange Mothers.

important in IR for startups.[19]

Figure 12: Number of IPOs and M&As in VC Exits (2016)



Source: Venture Enterprise Center "Venture White Paper 2017"

Third, both startups and VC funds are encouraged to establish intellectual property strategies while maintaining and developing professional human resources in their relevant areas. For instance, a survey of SMEs showed that about 40 percent of them pointed out that there is a shortage in people who manage intellectual property (Figure 13). Moreover, a report by the Japan Patent Office suggests that hands-on support by VC funds after investment[20] is not always sufficient, implying that there is room for improvement. At this stage, it appears that VC funds do not have enough internal staff to support intellectual property management (Figure 14) and there are cases where there is not sufficient collaboration with external intellectual property experts (such as lawyers and patent attorneys). Looking ahead, VC funds are encouraged to enhance their capacity for intellectual property support in tandem with establishing intellectual property strategies in order to promote startup innovation.

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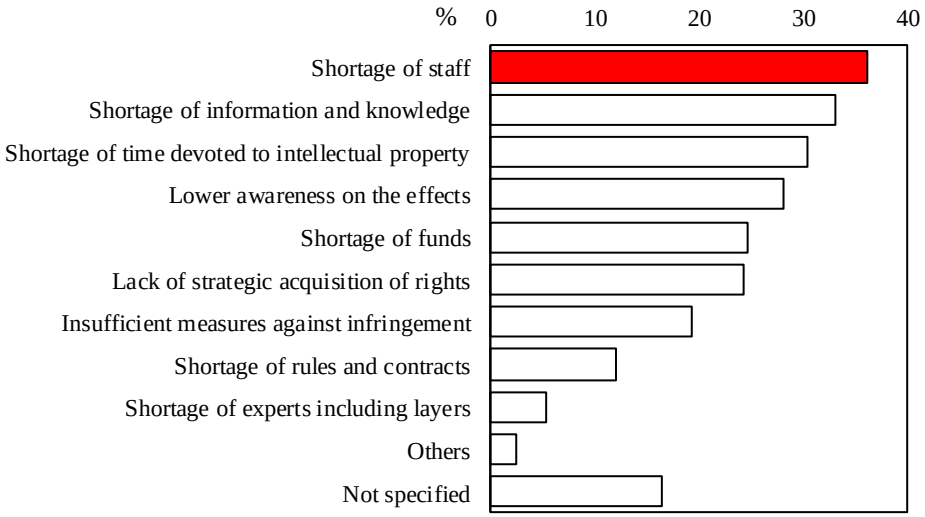
[19] For instance, see the discussions by the Study Group for Encouraging Dialogue between Biotech Venture Businesses and Investors hosted by the Ministry of Economy, Trade, and Industry. Meanwhile, the Tokyo Stock Exchange released in 2019 guidance on IPOs by biotech startups that require upfront investments and showed the need for rational business planning and appropriate disclosure.

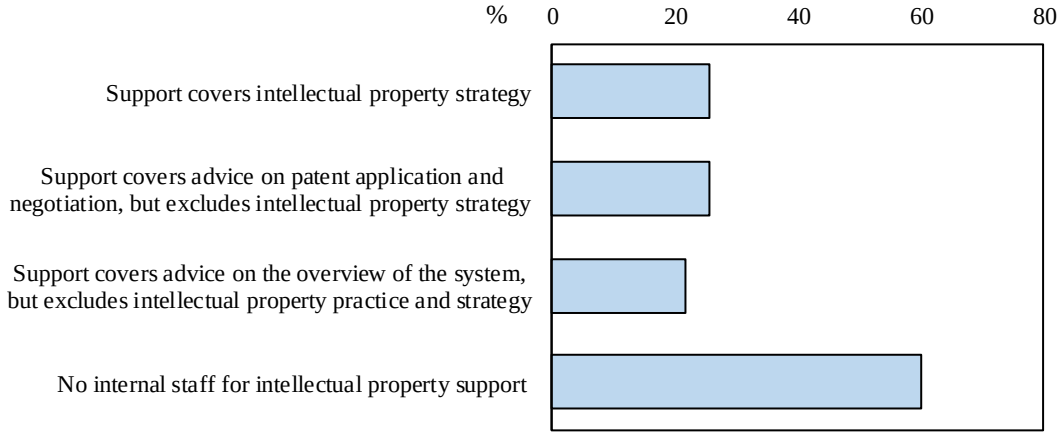
[20] According to that report, many VC funds mentioned the following specific hands-on support for portfolio companies: whether they have acquired patents to cover their business model; whether they can judge the need to acquire patents or conceal an invention depending on their business model etc.

Figure 13: Challenges in Intellectual Property Activity (SMEs)



Source: Japan Patent Office "Fundamental Survey for Intellectual Property Activity of SMEs (2019)"

Figure 14: Survey on Intellectual Property Strategies (VC Funds)

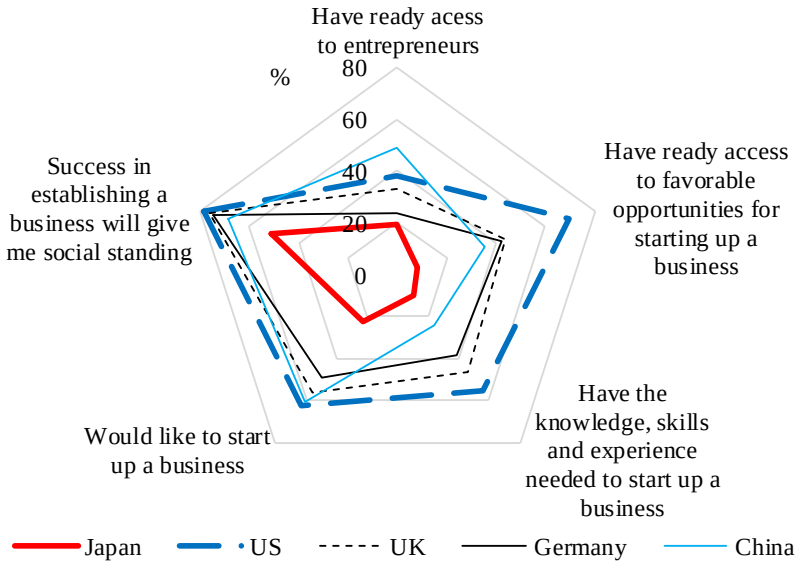


Source: Mizuho Information and Research Institute "Report on Optimum Intellectual Property Support for an Appropriate Evaluation on Startups (2019)" *Japanese only*

Lastly, public awareness of startups and VC funds is expected to also further improve. According to an international survey (Figure 15), the perceived image of entrepreneurs is less positive in Japan than other countries, and Japanese people tend to feel that there is not an adequate external environment to start a business. That said, even under those

circumstances, the number of university-initiated startups has increased in recent years,[21] leading to the launch of startups and the creation and expansion of new businesses by students. Efforts to increase entrepreneurs and potential entrepreneurs are also needed to increase the number of venture capitalists that have practical experience in starting businesses. To that end, as this paper attempts to show, there should be further analysis and the public should be informed about how startups and VC funds would specifically have a positive impact on the economy.

Figure 15: International Comparison of Entrepreneurial Awareness



Note: Based on the results of the Global Entrepreneurship Monitor Surveys.
Source: Mizuho Information and Research Institute "Survey of Entrepreneurial Spirit (2019)"

5. Conclusion

This paper provides an overview of patent applications by Japanese startups and reviews the impact of VC investments on innovation by portfolio companies, with a focus on the number of patent applications as a proxy of innovation. In fact, an estimation of the impact of VC financing on innovation suggests that the number of patent applications by portfolio companies significantly increased compared to a control group in about 60

[21] A 2020 survey by the Ministry of Economy, Trade, and Industry shows that the number university-initiated startups increased from 1,749 to 2,566 between FY 2014 and FY 2019.

percent of cases. While care should be taken in interpreting those studies as the results could vary across firms, those successful cases reflect the possibility that financing and management support including intellectual property management from VC funds could have contributed to an increase in patent applications.

Challenges ahead include: (1) expanding investments in VC by institutional investors; (2) increasing opportunities for startups to go public in a way that encourages the sustainable growth; and (3) establishing intellectual property strategies while maintaining and developing professional human resources in relevant areas. In recent years, as an open innovation tax incentive[22] was introduced, investments in startups by non-financial corporates and corporate venture capital (CVC) funds are expected to further increase.[23] Going forward, Japanese firms are expected to make progress in innovation with initiatives to tackle those challenges.

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[22] That tax incentive provides an income deduction equal to 25 percent of the amount invested in companies when acquiring more than a certain amount of newly issued shares of startups. For example, M&As by non-financial corporates and investments by CVC funds are eligible for that tax incentive.

[23] For instance, see Kouda (2019) for the circumstances surrounding open innovation in Japan.

(Appendix) Impact of VC Investments on Innovation by Portfolio Companies: Synthetic Control Method Using a Bayesian Structural Times Series Model

The synthetic control method (SCM) measures the impact of an event by comparing A (treatment) and B (synthetic control), which is artificially constructed as a counterfactual of A without the event.[24] The main advantages are that this approach can perform causal inference with a small sample, and construct B in a data-driven way by a weighted average of controls (panel data) that have similar characteristics to A.

Nevertheless, given that patent application paths could significantly vary across firms, it would be difficult to construct a counterfactual of A by a weighted average of controls. Therefore, this paper uses a Bayesian structural time series model[25]—a more flexible model estimation—and construct synthetic controls, following previous studies (Brodersen et al. (2015)). In effect, it predicts the number of patent applications using synthetic controls based on a regression component that uses the number of patent applications by a control group (which are similar to the treatment group but do not receive financing from VC funds), and constructs a counterfactual of A.

As one feature, the model estimates parameters by Gibbs sampling while decomposing into a trend component and a regression component by a state space model based on the information before the treatment group receives financing from VC funds. It can also calculate a posterior distribution and confidence intervals on the number of patent applications by synthetic controls using the Markov Chain Monte Carlo method.[26]

- For treatments, the treatment group is selected from firms that have applied for patents in multiple years, and that is then narrowed down to 24 firms that satisfy the

[24] For details, see Abadie et al. (2011).

[25] Kinn (2018) compares traditional SCM and SCM using a Bayesian structural time series model. While the latter is robust against outliers and noise, it should be noted that there might be a decline in estimation accuracy in the case of a short sample period up to Year T.

[26] Other features include an assumption that a spike-and-slab prior distribution can perform variable selection by sparse estimation (Scott and Varian (2013)). As an application, for instance, Selod and Soumahoro (2020) examines the impact of the lockdown during the COVID-19 crisis on traffic congestion in selected metropolitan areas.

following conditions: the year of initial VC funding is (1) at least three years after the establishment of the company and (2) no later than 2016.

- The control group consists of several startups that are in similar sectors and have firm ages that are similar to the treatment group among those have applied for patents in multiple years (more than five applications in total).

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