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Local Industry Influence on Commercialization of University Research by University Startups

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Local industry influence on commercialization of university research by university startups[1]

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Abstract

This study investigates how regional conditions affect university startups using data from Japan. We use the list of university startups compiled by METI, covering more than 2,000 firms, linked with JPO patent information. The study found that technical field of patents obtained by university startups are influenced by local industry characteristics. In addition, in terms of commercialization of university patents, commercialization by university startups is more locally proximate, as compared to cases realized through university industry collaborations. Our results provide implications that regional conditions must be considered when setting academic entrepreneurship policies.

Keywords: University Startup; Technology Commercialization; Japan
JEL classification: L26, O32, R11

[1] This study is conducted as a part of the Project ”Digitalization and Innovation Ecosystem: A Holistic approach” undertaken at the Research Institute of Economy, Trade and Industry (RIETI)

1. Introduction

University startups are often modeled as a technology push model (Shane, 2004). In industries where technology is vital, characteristics of technology determine its entrepreneurial opportunities for technology startups (Marsili, 2002). For example, technological advanced, radical, and broadly protected university patents are likely commercialized through the establishment of university startups (Shane, 2001a).

Meanwhile, many studies indicated that entrepreneurship is generally attributed to regional conditions. Culture, education, environment, institution, and talent are often mentioned as those regional conditions (Sternberg, 2009). They considered regional conditions as surrounding elements that were independent from characteristics of technology.

This study assumes that regional conditions, focusing on local industry characteristics, affect commercialization of university research by the form of academic startups. We use data on university startups in Japan that are reported to the Ministry of Economy, Trade and Industry (METI). The data contain the full list of university startups established until 2018, linked with the JPO patent information to test the influence the demand factor (local industry) on academic startups.

This study has two contributions. First, we add a regional context as a new element into the characteristics of technology developed in universities. There are numbers of studies, addressing the role of academic research on the growth of regional innovation ecosystem and local economy (Lowe, 2001; Shane, 2001b; Youtie & Shapira, 2008), but only a few studies included regional context in their analyses.

Second, this study defines types of university startups. Prior arguments were made with evidence from different types of startups; some argued with evidence from startups founded by students, whereas others argued with those founded by faculty members. As our result will show, characteristics of technology determine the establishment of university startups differently for their types.

The remainder of the paper is organized as follows: Section 2 reviews literature on which this study is based and sets hypotheses to test, and Section 3 explains the research data. Section 4 presents our data analyses, and Section 5 concludes with remarks on the policy implications and the limitations of this study.

2. Literature review and hypotheses

Knowledge input from industry is integral in the commercialization of university technology. Many universities encourage their academic staff to commercialize research outcomes (Kneller, 2007; Grimaldi et al., 2011). It is not easy, however, for academic researchers to commercialize research outcomes unaided (Rasmussen et al., 2006). Collaboration with industries helps with commercialization (Wu et al., 2015). Industry partners provide insights that are based on real problems (Agrawal & Henderson, 2002). Therefore, university research becomes closer to industry needs. Industry partners can guide the direction of commercialization when academic researchers are confused on where to utilize their research outcomes. Researchers look for information on industry problems, feedbacks from industries, and applicability of their research (D'Este & Perkmann, 2011). Knowledge input from industries stimulates the commercialization of university technology (Wong & Singh, 2013). The technology is more likely to be commercialized when a university technology is developed with an industry partner.

We hypothesize that knowledge near universities affects the commercialization of university technologies. The first reason is that knowledge tends to be localized (Jaffe et al., 1993; Agrawal et al., 2006; Arora et al., 2018). Although knowledge flows through various channels, its flow decreases with distance. Accordingly, universities focus on regional knowledge base rather than on distant knowledge base. Second, each region forms specialized industrial sectors. Empirical studies show that formation of industrial regions is attributable to local conditions (Dorfman, 1983; Feldman & Florida, 1994; Kenney & von Burg; 1999; Antonelli, 2000; Koo, 2007; Yamada & Kawakami, 2016; Li, 2017). Each region has different environmental conditions; therefore, regional knowledge base exists in different fields for each region. For that reason, it is assumed that university commercialization effort is influenced by knowledge that is relevant to local industries. Therefore, we test the hypothesis:

H1. University patents are likely to be commercialized in the technological fields where disproportionally large numbers of local industry inventions are found in the region.

In addition, it is found that knowledge spillover occurs more densely when social ties are strong between actors. An empirical study on Mexico indicated interactions between firms and universities from different regions generally shared codified forms of knowledge. In contrast, interactions between firms and universities from the same region shared tacit forms of knowledge (De Fuentes & Dutrénit, 2016). In addition, the type of commercialized technology in university via collaboration is influenced by the partner company, while the commercialization by university startup is more independent, and more purely influenced by local industry characteristics. Therefore,

H2. University patents commercialized by university startup are more likely to be influenced by the technological characteristics of its location region, as compared to those patents commercialized by firm collaboration.

3. Overview of academic startups in Japan (METI's Survey)

METI (Ministry of Economy, Trade and Industry) has conducted academic startup survey annually, to come up with its list for more than 10 years. The respondents are universities (including technical college), TLOs (Technology Licensing Organizations), prefecture local governments and regional technology incubators. The response rate is high. For example, in 2017, METI received 638 responses from 994 target organizations (64.2% Reponses). The survey asks the respondents the following information: firm name, founder(s)'s name, foundation date, contacts, corporate number, industry type, main products and services, relevant universities and TLOs, and type of startups. Finally, METI further fills in the information for some startups (mainly unanswered university ones), by using existing database as well as any publicly available information such as university websites, any types of firm information.

The following information is based on the list on February 21, 2019 (METI, 2019), which contains the information of 2,524 startups[1]. METI defines five types of university startups, as is shown in Table 1. Of 2,524 startups, more than half of them are research outcome startups, and about 20% are student startups, which implies that research outcomes are usually commercialized within the university rather than from outside. This implication becomes more apparent from the university patents that are commercialized by university startups.

Table 1. Types of university startups

Startup types and definition	Univ. startups	
	Counts	%
Research outcome startup Commercialize patents, technologies, and business models produced as research outcomes in universities	1,438	57.0
Student startup Founded by students	500	19.8
Collaborative research startup Collaborate with universities to commercialize founder's technologies and knowhows within 5 years from foundation	238	9.4
Relevant startup Invested by universities, etc.	163	6.5
Technology transfer startup Get technology licenses from universities to develop current business within 5 years from foundation	104	4.1
Unidentified	84	3.3
Total	2,524	100.0

Figure 1 shows the trend of academic startup foundation in Japan. It indicates that startups are influenced by economic situations to some extent.

Until 1994, there had been up to 10 university startup foundations. In 1995, Science and Technology Basic Law was enacted to tackle economic and social development issues (Okamuro et al., 2019). Since 1995, the number of university startup foundations had increased until 2005. That period almost overlaps with the dot-com bubble and biotech venture boom. Moreover, METI has formulated university-industry collaboration (UIC) promotion policies since 1995 (See Appendix A for details). One of them is the Hiranuma plan commenced in 2001. It was aimed at creating 1000 university startups between 2002 and 2004 and fostering an environment for further startups.

[1] Out of 2,524 startups, 246 closed their business and 2,278 are still doing their business.

University startups decreased between 2006 and 2010. Events in this period had adverse effects on startups. The dot-com bubble and biotech venture boom ended around 2005, and an iconic Japanese entrepreneur was arrested for his company's financial scandal in 2006. The critical event was the US subprime mortgage crisis between 2007 and 2010.

The decrease did not last long. Since 2011, the number of university startup foundations has been increasing again. The increase is not irrelevant to social change. Evolution to a digital economy dramatically speeded up in the 2010s and is represented by the dissemination of smartphones, Internet of things, financial technologies, and artificial intelligence applications. They opened new opportunities such as the fourth industrial revolution, rapid growth in health care businesses, and emergence of the sharing economy. University startups are also active in such business areas (Figure 2).

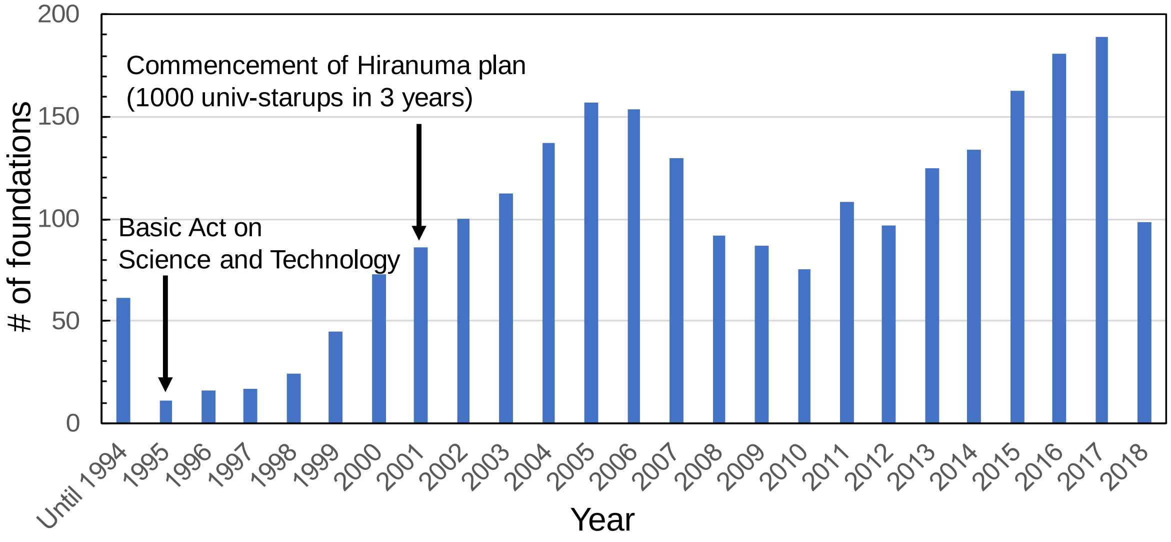


Figure 1. University startups in Japan

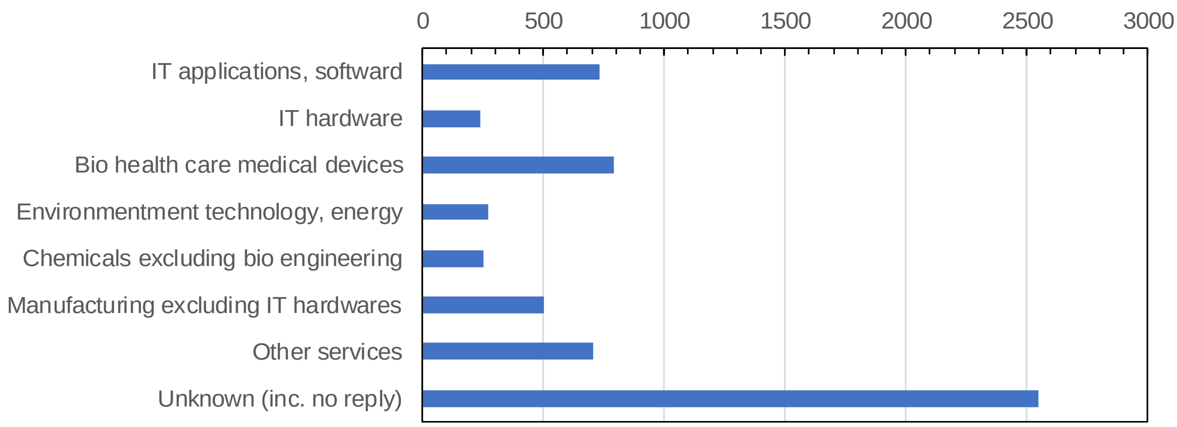


Figure 2. Business area of university startups

There are many commercializing scenarios in university startups, and they can be classified in several ways. Table 1 defines five types of university startups on the basis of commercializing scenarios: research outcome startups, student startups, collaborative research startups, relevant startups, and technology transfer startups.

Table 2 notes the top 20 alma mater universities of startups; our sample has 279 universities and their TLOs. In Table 2, the distribution of university startups is highly skewed as the University of Tokyo and Kyoto University account for 45% of all them in Japan. Research grants and environments are unequal at the university level (Kneller, 2007; Shibayama, 2011). Large-size grants and UICs concentrate on several research universities, which include national universities and a few private universities. Such functional research environments may result in dynamic university startups activities. That idea is further supported when startup activity is compared with patent filing. Universities that produce a lot of startups also file a lot of patents (correlation: 0.787). Accordingly, research universities with functional research environments are generally active in the commercialization of their technologies.

Table 2. Top 20 alma mater of university startups

Alma mater university (*: private university)	No. of univ startups	No. of patent applications
University of Tokyo	658	4,590
Kyoto University	489	3,128
Osaka University	204	3,515
Tohoku University	183	4,322
Keio University*	158	1,620
University of Tsukuba	121	1,037
Kyushu University	115	2,315
Tokyo Institute of Technology	98	3,107
Nagoya University	95	2,244
Waseda University*	82	1,196
Hiroshima University	60	1,690
Digital Hollywood University*	56	0
Hokkaido University	54	1,909
Kyushu Institute of Technology	53	1,153
Ryukoku University*	46	198
Kobe University	40	1,098
Ritsumeikan University*	39	727
University of Aizu	36	59
Doshisha University*	35	677
Okayama University	35	944

As is expected from Table 2, academic startups are not even distributed in all over Japan. Figure 3 shows the share of the numbers of academic startups by 47 prefectures in Japan. It is found that 30% of academic startups are concentrated in Tokyo, leading to Osaka, Kyoto and Kanagawa (6%) with a big margin.

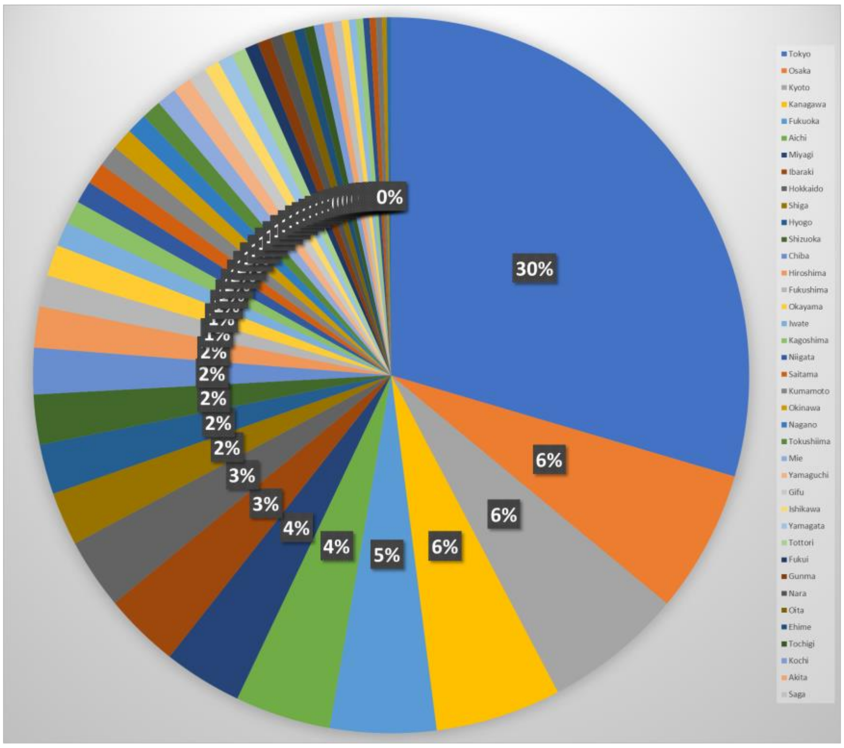
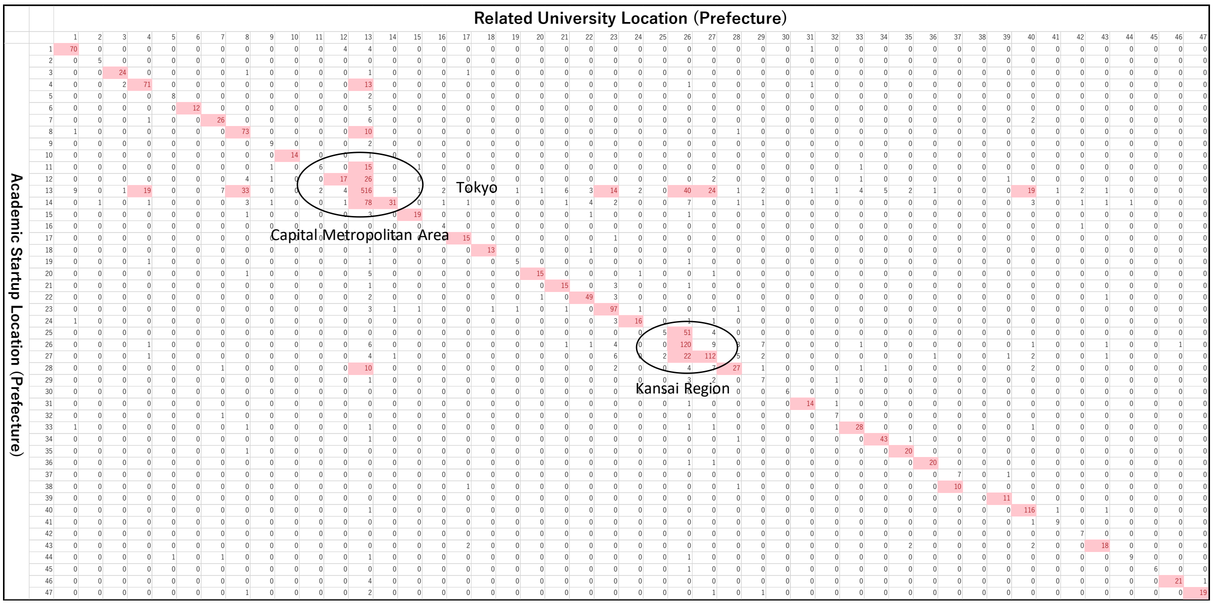


Figure 3. % of academic startups by prefecture

Table 3 shows a corresponding table of the location (prefecture) of a startup firm and the location (prefecture) of the university as its origin. The cells with more less than 10 firms are shaded with red. The diagonal cells correspond to the case of being located in the same prefecture. Among 2,510 startups[2], 1,762 (70%) are founded in the prefecture where their university headquarters is located. Therefore, 30% of startups are located in off-diagonal cells, i.e., starting business outside the prefecture of its origin university. However, many of these firms moves within Tokyo capital metropolitan area (including Tokyo, Kanagawa, Chiba and Saitama), or Kansai Area (including Osaka, Kyoto, Nara and Hyogo). In addition, there are also substantial numbers of firms coming to Tokyo, or going out of Tokyo. To sum up, the geographical proximity to its origin university is high in general, except for the cases of moving in/out of Tokyo.

Table 3. Location prefecture of startup and origin university

[2] University startups that did not indicate their university were excluded.



4. Dataset

In order to understand the relationship between the influence of local industry characteristics and the startup business, we have constructed the linked database of METI survey (as of February 21, 2019) with the IIP Patent Database (2020 version containing all patent publication record until September 2020), made from JPO patent information (Goto & Motohashi, 2007). The linkage is conducted by approximate matching of firm names, as well as location information. All address information is geocoded and then all matching candidates from patent applicant names with each startup name selected within 0.1 range of longitude and latitude (about 10km at the location of Japan). The Jaccard index of bigrams of name strings with inverse log weight is calculated for each candidate pairs to select matching pairs[3]. Then, it is found that 884 out of 2,510 firms have at least one patent application with a total of 6,829 patents.

Table 4 shows the number of matched samples (with patent application), by the location of firm, whether it locates in the same prefecture as its origin university. The share of the same prefecture firms is almost same for with and without patent samples, while its share for with patent group is a bit lower (67%, as compared to 72% for no patent group).

Table 4. Location type by with or without patents

	Same Pref	Not Same	Total
With Patent	594	290	884
Without Patent	1,168	458	1,626
Total	1,762	748	2,510

[3] We use 0.75 for the cutoff value of the Jaccard index after manual check of random sample of approximate matching results.

Table 5 shows the shares of with patent and same pref firms by the type of academic startups (presented in Table 1). It is natural to see that the shares of with patent firms are higher for technology based startups (such as "research outcome", "collaborative R&D", "technology transfer"), as compared to the other groups ("student startups", "other related, such as university investment"). The shares of the same pref firms are not so different across firm types. Student startups are more regionally bounded by its origin, while it is lower for collaborative R&D startups, where a company starts independently, and collaborate with university later.

Table 5. Number of firms by type of academic startups

	With Patent	Same Pref	# of firms
Research outcome	39.1%	70.7%	1,429
Student	17.9%	78.9%	497
Collaborative R&D	50.4%	50.8%	236
Technology Transfer	43.3%	69.2%	104
Other related	26.7%	67.1%	161

Finally, we have developed an indicator for local industry characteristics by using patent database. Specifically, the calculated the share of patents by IPC class as follows,

$$IPC1_{i,p,y} = \frac{n_{i,p,y\_app}}{\sum_i n_{i,p,y\_app}}$$

where *n* is the number of firm patents, *i* is the IPC (three digit IPC code), *p* is prefecture, and *y_app* is year. The same indicator by using the patent counts for three years is also developed for robustness check, as follows,

$$IPC3_{i,p,y} = \frac{\sum_{y=y\_app-2}^{y\_app} n_{i,p,y}}{\sum_{y=y\_app-2}^{y\_app} \sum_i n_{i,p,y}}$$

The annual average of patent counts as and HHI (Herfindahl Hirschman Index) for technological concentration (or diversification), by using IPC1 and IPC3, by prefecture are presented at Appendix B.

5. Regression Analysis

Our strategy of testing the hypotheses in section 2 is comparting patents by university startups and those of universities. Therefore, our samples include (1) the patents by university startups (6,829), (2) the patents by university only (19,948) and (3) the patents by joint application of university and firm (13,098). There are 465 patents of joint application of university and university startup, which is treated as the first category, instead of the third one. Therefore, the third category is more precisely called the patents by joint application of university and non-university startup firms. The first hypothesis compares IPC1 or IPC3 across the first and the second, and the second hypothesis is using the first and the third groups for statistical testing. Therefore, the dependent variable is startup dummy for both cases, and the key independent variable is IPC1 (or IPC3), reflecting regional characteristics of industry patents (the share of IPC class for the corresponding to the same IPC class, prefecture and application year of each patents for all three groups).

In the regression mode, we control for the heterogeneity of patent quality by using normalized non-self citation, radicalness index and the number of claims. First, we calculated the normalized number of non-self forward citations, which is obtained with the number of non-self forward citations divided by the average number of forward citations from the same application year and IPC (Jaffe & Trajtenberg, 2002). The interpretation of forward citation is that the more a patent is cited by follow-up patents, the more technologically relevant it is. Normalization controls the age effect that older patents have more citations than newer patents.

Second, radicalness is measured with the number of technological fields in which previous patents cited by the given patent are found, but the patent itself is not classified (Rosenkopf & Nerkar, 2001; Shane, 2001a). Among all the control values, an arguable variable is radicalness. There have been long discussions on how to measure radicalness of a patent (Dahlin & Behrens, 2005), and this study uses the definition used by Shane (2001a) for two reasons. First, our analytic model is based on Shane (2001a). Second, the definition of Shane (2001a) is used by official reports, e.g., Squicciarini (2013).

Finally, the number of claims at patent application is used for controlling the technical broadness of each patent. We also include prefecture dummies and application year dummies as controlling variables. The results are presented in Table 6 and Table 7.

(Table 6), (Table 7)

In Table 6, we tested the hypothesis 1 by using three types of dataset, all samples, samples with university and firm are located in the same prefecture for U-I joint application patents, and samples with only single applicant patents (by university startup or university only). It should be noted that IPC1 and IPC3 is the share of industry patent counts by IPC class corresponding to each regression sample in the prefecture of university location, in case of joint U-I patents. The coefficients to IPC1 and IPC3 are all positive and statistically significant at 1% level.[4] Therefore, the hypothesis 1 is supported.

[4] Same is a dummy variable for the joint application patents with the applicant located in the same prefecture. Collab is a dummy variable for the joint application patents (in stead of single applicant patents) in Table 6 and Table 7.

It is also found that the number of non self forward citations and the number of claims are greater for university startup patents, as compared to university ones, while there is not statistically significant difference (or only small difference) in terms of the radicalness index.

Table 7 shows the statistical test for the hypothesis 2. Here, university patents are compared with UI collaboration patents, and the IPC1 and IPC3 is the industry patents share, by using *firm's location* in case of UI collaboration patents. Again, the coefficients to IPC1 and IPC3 are all positive and statistically significant at 1% level, suggesting that the hypothesis 2 is supported. As regards to the comparison between university startup patents, and UI collaboration patents, the statistically significant difference can be found only in the number of claims, and not in the other two types of quality indicators.

We have further investigated the same issue by looking into heterogeneity in university startups. As is shown in the section 2, the type of startup (5 types: research outcome, joint R&D, technology transfer, student, other related such as university investment) information is available in the METI's survey. We compared the proximity to the regional technological characteristics, by using multinomial logit model (using research output startup as a base category). The results are presented in Table 8.

(Table 8)

The coefficients to IPC3 is positive and statistically significant for technology transfer startup, while it is negative and statistically significant for other related startups (such as investment). In contrast, it is not statistically significant in the other two types (collaborative research and student startups). Therefore, the order of local proximity is like, (1) technology transfer, (2) research outcome, collaborative research, student, then (3) other related startups. It should be noted that patents in collaborative research and technology transfer startups are greater in its non-self forward citation, as compared to those in research outcome startups. In addition, patents of research outcome startups are broader in its legal scope, measured by the claim counts, as compared to those of collaborative research and student startups.

6. Conclusions with implications

This study investigates how regional conditions affect university startups using data in Japan. It is found that the technology field of patents of university startups are more influenced by local industry characteristics, as compared to the university patents of their origins. In other words, the patents in the technology fields where local industry patents are more applied, are likely to be commercialized via university startups, among a whole population of university patents. It is also found that such local industry proximity of university startup patents is greater than that of university patents collaborated with the firms other than university startups. These findings suggest that the local firms play an important role for foundation and growth of university startups. Furthermore, a substantial heterogeneity in university startups in terms of local industry proximity is observed.

Our findings provide several policy implications. First, university startup policies must be designed based on technological fields that are relevant to regional economies. This study indicates that startups are likely to occur in technological fields where a regional economy has competency and specialty. Those startups can upgrade and reinvigorate regional competitiveness, specialty, and economies.

Second, interactions with universities and their local industries must be encouraged. Practical knowledge from industries is essential in commercializing university technologies. Such interactions can let university researchers understand local technological needs and find commercialization opportunities for their technologies.

Third, universities must be prepared to respond to regional needs whenever required. However, this does not mean that universities should only keep departments relevant to regionally competitive and specialized fields. The focus of this study is limited to university startups, but there are other ways for universities to contribute to regional economies with other approaches.

To conclude, this study has some limitations. One limitation is that we used patent data as business seeds of university startups. As we have seen, among all startups, only about 35% of them have ever filed patents. Moreover, we used patents co-applied by universities and their startups as commercialized university technologies via entrepreneurship. However, it is very challenging to obtain the whole list of commercialized university technologies because firms are reluctant and sensitive to disclosing business ideas.

Table 6. Regression results (University startup vs University patents)

	All sample		Same prefecture		Single applicant	
ipc1	3.844 (5.26)**		4.492 (6.01)**		5.286 (6.65)**	
ipc3		4.361 (5.59)**		5.084 (6.38)**		6.105 (7.18)**
nonself	0.042 (3.94)**	0.043 (4.03)**	0.045 (4.14)**	0.046 (4.25)**	0.056 (4.87)**	0.057 (5.00)**
radical	0.018 (2.02)*	0.017 (2.00)*	0.017 (1.90)	0.017 (1.87)	0.015 (1.63)	0.015 (1.59)
claim	0.021 (7.31)**	0.021 (7.33)**	0.019 (6.62)**	0.019 (6.64)**	0.019 (6.40)**	0.019 (6.44)**
same	1.365 (9.88)**	1.365 (9.88)**				
collab	-1.630 (18.72)**	-1.631 (18.73)**	-1.641 (18.88)**	-1.643 (18.89)**		
constat	-1.099 (3.48)**	-1.103 (3.52)**	0.270 (0.92)	0.266 (0.92)	0.287 (0.94)	0.266 (0.88)
Prefecture dummy	yes	yes	yes	yes	yes	yes
Year dummy	yes	yes	yes	yes	yes	yes
# of observations	20,317	20,318	15,577	15,578	12,194	12,195

* p <0.05; ** p <0.01

Table 7. Regression results (University startup vs U-I collaboration patents)

	Ustartup + UI collab		Ustartup + UI collab Same prefecture	
ipc1	3.012		5.464	
	(3.08)**		(4.81)**	
ipc3		3.152		5.754
		(3.06)**		(4.80)**
nonself	-0.009	-0.009	-0.005	-0.004
	(0.68)	(0.64)	(0.36)	(0.30)
radical	0.022	0.022	0.022	0.023
	(1.83)	(1.83)	(1.71)	(1.72)
claim	0.035	0.035	0.031	0.031
	(8.17)**	(8.19)**	(7.14)**	(7.18)**
same	6.111	6.110		
	(39.74)**	(39.74)**		
constat	-4.650	-4.635	1.335	1.347
	(12.24)**	(12.25)**	(3.59)**	(3.64)**
Prefectuer dummy	yes	yes	yes	yes
Year dummy	yes	yes	yes	yes
	12168	12169	6506	6507

* *p* <0.05; ** *p* <0.01

Table 8. Regression results (by type of university startup)

(multinomial logit: “Research Outcome Startup” for base category)

	Collarative Research	Tech Transfer	Student	Other related
ipc3	0.023	4.010	0.116	-7.963
	(0.02)	(2.66)**	(0.08)	(2.48)*
nonself	0.051	0.115	-0.009	0.054
	(2.90)**	(4.37)**	(0.33)	(1.38)
radical	0.022	0.036	0.037	-0.011
	(1.47)	(1.53)	(1.94)	(0.31)
claim	-0.021	-0.014	-0.033	-0.002
	(4.04)**	(1.61)	(3.62)**	(0.31)
constat	-1.508	-3.345	0.592	-2.359
	(3.78)**	(4.51)**	(2.35)*	(3.75)**
Prefectuer dummy	no	no	no	no
Year dummy	yes	yes	yes	yes

# of observation: 4,120 ; * p <0.05; ** p <0.01

Appendix A: History of UIC promotion policies in Japan

Table A reviews the history of UIC promotion policies in Japan since 1995. These policies are formulated to promote commercialization of technologies in universities through patenting, startups, and technology transfer. The history indicates how university startups are promoted by those policies.

Table A. History of UIC promotion policies in Japan

Year	Action
1995	• Formulation of the Basic Act on Science and Technology → Formulation of Science and Technology Basic Plan
1998	• Formulation of the Act on the Promotion of Technology Transfer from Universities to Private Industry (the TLO Act) → Promoted the establishment of TLOs (Technology-Licensing Organizations)
1999	• Creation of the Small Business Innovation Research Program ("Japanese SBIR") • Formulation of the Act on Special Measures for Industrial Revitalization → Japanese version of the Bayh-Dole Act; licensing fee halved for approved TLOs • Establishment of the Japan Accreditation Board for Engineering Education
2000	• Formulation of the Industrial Technology Enhancement Act → Enabled the free use of national university facilities by approved/certified TLOs, and allowed university researchers to serve concurrently as TLO directors, board directors of companies commercializing research results, and statutory auditors of stock corporations
2001	• "Hiranuma Plan" announced as a "plan for a thousand university-originated ventures in three years"
2002	• The first University-Industry-Government Collaboration Promotion Meeting
2003	• Formulation of the Intellectual Property Basic Act → Obligated universities to voluntarily and actively seek to develop human resources, research activities, and disseminate research results • Amendment of the School Education Law → Created special emphasis on graduate school systems and increased flexibility in establishing university faculties/departments • The first Industry-University-Government Collaboration Contributor Commendation → Established a Prime Minister Prize to honor achievements in excellent, successful cases that significantly contributed to promoting university-industry-government collaborations
2004	• Implementation of the National University Corporation Law • → Status of university researchers: "non-civil servant type" capital contributions to

	approved TLOs • Implementation of an act to partially revise the Patent Act → Revision of patent-related charges relating to universities and TLOs
2005	• Achievement of 1,000 university-originated ventures (1,112 firms)
2006	• Revision of the Fundamentals of Education Act → Clarified "Contribution to Society (university-industry-government collaborations, etc.)" as a role of universities
Since 2008	• Establishment of advanced innovation, technology-bridging, and various clusters → Established facilities in which universities, industries, and the government can closely collaborate
2013	• Establishment of the Industrial Competitiveness Enhancement Act → National universities can invest in venture capital, among other functions.

Source: "History of university-industry-government collaboration," translated from the Ministry of Economy, Trade, and Industry's website.[5]

[5] http://www.meti.go.jp/policy/innovation_corp/sangakukeifu.html (last accessed on December 15th, 2019)

Appendix B: Summary table of patent indicator for local industry characteristics

	Count	Count (3 yrs)	HHI	HHI (3 yrs)
Tokyo	21968	66273	0.030	0.031
Osaka	7526	22692	0.027	0.027
Aichi	5050	15187	0.120	0.130
Kanagawa	4018	12079	0.046	0.047
Hyogo	1862	5618	0.026	0.025
Shizuoka	1560	4695	0.038	0.037
Gunma	1432	4271	0.303	0.306
Saitama	1425	4284	0.032	0.031
Ehime	1128	3398	0.124	0.122
Kyoto	1081	3264	0.041	0.040
Mie	1069	3184	0.160	0.158
Chiba	915	2741	0.045	0.044
Nagano	705	2123	0.052	0.050
Fukuoka	696	2101	0.034	0.032
Hiroshima	694	2087	0.039	0.037
Ibaraki	644	1937	0.059	0.057
Gifu	571	1717	0.044	0.041
Yamanashi	542	1633	0.081	0.077
Niigata	467	1404	0.047	0.044
Shiga	464	1398	0.090	0.087
Okayama	432	1301	0.070	0.067
Miyagi	369	1112	0.067	0.062
Hokkaido	351	1059	0.056	0.051
Ishikawa	347	1048	0.058	0.054
Yamagata	332	1003	0.102	0.096
Toyama	331	997	0.044	0.041
Tochigi	320	960	0.079	0.069
Fukui	300	908	0.058	0.053
Shimane	234	707	0.288	0.278
Yamaguchi	231	697	0.067	0.056
Tottori	228	685	0.097	0.084
Kagawa	196	592	0.057	0.046
Kumamoto	185	558	0.153	0.140
Nara	174	524	0.051	0.046
Fukushima	167	503	0.059	0.047
Wakayama	144	437	0.105	0.095
Iwate	142	429	0.103	0.087
Tokushiima	116	351	0.088	0.076
Kagoshima	90	276	0.132	0.110
Aomori	84	252	0.187	0.178
Saga	75	228	0.102	0.089
Akita	64	196	0.098	0.075
Kochi	64	193	0.093	0.070
Nagasaki	63	191	0.084	0.064
Miyazaki	63	191	0.103	0.071
Oita	63	190	0.089	0.067
Okinawa	44	134	0.123	0.094

Reference

Arora, A., Belenzon, S., & Lee, H. (2018) Reversed citations and the localization of knowledge spillovers, Journal of Economic Geography 18(3), 495–521.

Agrawal, A., Cockburn, I., & McHale, J. (2006) Gone but not forgotten: Knowledge flows, labor mobility, and enduring social relationships, Journal of Economic Geography 6(5), 571–591.

Agrawal, A., & Henderson, R. (2002) Putting Patents in Context: Exploring Knowledge Transfer from MIT, Management Science 48(1), 44–60.

Antonelli, C. (2000) Collective knowledge communication and innovation: the evidence of technological districts, Regional Studies 34(6), 535–547.

Boschma, R. (2005) Proximity and innovation: a critical assessment, Regional Studies 39(1), 61–74.

Cuba, L., & Hummon, D.M. (1993) A place to call home: Identification with dwelling, community, and region, Sociological Quarterly 34(1), 111–131.

D'Este, P., & Perkmann, M. (2011) Why do academics engage with industry? The entrepreneurial university and individual motivations, Journal of Technology Transfer 36(3), 316–339.

Dahlin, K.B., & Behrens, D.M. (2005) When is an invention really radical?: Defining and measuring technological radicalness, Research Policy 34(5), 717–737.

De Fuentes, C., & Dutrénit, G. (2016) Geographic proximity and university–industry interaction: the case of Mexico, Journal of Technology Transfer 41(2), 329–348.

Dorfman, N.S. (1983) Route 128: The development of a regional high technology economy, Research Policy 12(6), 299–316.

Feldman, M.P., & Florida, R. (1994) The geographic sources of innovation: Technological infrastructure and product innovation in the United States, Annals of the Association of American Geographers 84(2), 210–229.

Goto, A., & Motohashi, K. (2007) Construction of a Japanese patent database and a first look at Japanese patenting activities, Research Policy 36(9), 1431–1442.

Grimaldi, R., Kenney, M., Siegel, D.S., & Wright, M. (2011) 30 years after Bayh-Dole: Reassessing academic entrepreneurship, Research Policy 40(8), 1045–1057.

Jaffe, A.B., & Trajtenberg, M. (Eds.) (2002) Patents, citations & innovations: A window on the knowledge economy. The MIT Press, Cambridge.

Jaffe, A.B., Trajtenberg, M., & Henderson, R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations, Quarterly Journal of Economics 108(3), 577–598.

Kenney, M., & von Burg, U. (1999) Technology, entrepreneurship and path dependence: industrial clustering in Silicon Valley and Route 128, Industrial and Corporate Change 8(1), 67–103.

Kitson, M., Martin, R., & Tyler, P. (2004) Regional competitiveness: An elusive yet key concept?, Regional Studies 38(9), 991–999.

Kneller, R. (2007) The beginning of university entrepreneurship in Japan: TLOs and bioventures lead the way, Journal of Technology Transfer 32(4), 435–456.

Koo J. (2007) Determinants of localized technology spillovers: role of regional and industrial attributes, Regional Studies 41(7), 995–1011.

Li, X. (2017) Exploring the spatial heterogeneity of entrepreneurship in Chinese manufacturing industries, Journal of Technology Transfer 42(5), 1077–1099.

Lowe, R.A. (2001) The role and experience of start-ups in commercializing university inventions: Start-up licensees at the University of California, G. Libecap, ed. Entrepreneurial Inputs and Outcomes. Amsterdam, The Netherlands: JAI Press, 189–222.

Marsili, O. (2002) Technological regimes and sources of entrepreneurship, Small Business Economics 19(3), 217–231.

METI (2019), Report of university startup survey 2018FY, provided by Value Management Institute Inc., February 2019 (in Japanese)

Okamuro, H., Nishimura, J., & Kitagawa F. (2019) Multilevel policy governance and territorial adaptability: evidence from Japanese SME innovation programmes, Regional Studies 53(6), 803–814.

Ponds, R., van Oort, F., & Frenken, K. (2007) The geographical and institutional proximity of research collaboration, Papers in Regional Science 86(3), 423–443.

Powell, W.W. (1998) Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries, California Management Review 40(3), 228–240.

Rasmussen, E., Moen, Ø., & Gulbrandsen, M. (2006) Initiatives to promote commercialization of university knowledge, Technovation 26(4), 518–533.

Rosenkopf, L., & Nerkar, A. (2001) Beyond local search: Boundary spanning, exploration and impact in the optical disk industry, Strategic Management Journal 22(4), 287–306.

Shane, S. (2001a) Technological opportunities and new firm creation, Management Science 47(2), 205–220.

Shane, S. (2001b) Technology regimes and new firm creation, Management Science 47(9), 1173–1190.

Shane, S. (2004) Academic Entrepreneurship: University Spinoffs and Wealth Creation. Cheltenham: Edward Elgar.

Shibayama, S. (2011) Distribution of academic research funds: A case of Japanese national research grant, Scientometrics 88(1), 43–60.

Siegel, D.S., Waldman, D.A., Atwater, L.E., & Link, A.N. (2003) Commercial knowledge transfers from universities to firms: improving the effectiveness of university-industry collaboration, Journal of High Technology Management Research 14(1), 111–133.

Squicciarini, M., Dernis, H., & Criscuolo, C. (2013) Measuring Patent Quality: Indicators of Technological and Economic Value, OECD Science, Technology and Industry Working Papers, No. 2013/03, OECD Publishing, Paris, https://doi.org/10.1787/5k4522wkw1r8-en.

Sternberg, R. (2009), Regional Dimensions of Entrepreneurship, Foundations and Trends in Entrepreneurship 5(4), 211–340

Wong, P.K., & Singh, A. (2013) Do co-publications with industry lead to higher levels of university technology commercialization activity, Scientometrics 97(2), 245–265.

Wu, Y., Welch, E.W., & Huang, W.-L. (2015) Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents, Technovation 36–37, 12–25.

Yamada, E., & Kawakami, T. (2016) Distribution of industrial growth in Nagoya metropolitan area, Japan: An exploratory analysis using geographical and technological proximities, Regional Science 50(11), 1876–1888.

Youtie, J., & Shapira, P. (2008) Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development, Research Policy 37(8), 1188–1204.