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Knowledge Creation and Dissemination by Local Public Technology Centers in Regional and Sectoral Innovation Systems: Insights from patent data

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Knowledge Creation and Dissemination by Local Public Technology Centers in Regional and Sectoral Innovation Systems: Insights from patent data*

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Abstract

Local public technology centers (LPTCs) in Japan help small- and medium-sized enterprises (SMEs) improve productivity through technology transfer. Using a comprehensive patent database and based on frameworks of regional and sector innovation systems, this study quantitatively evaluates LPTCs' technology transfer activities. The key findings can be summarized as follows. First, local SMEs' technological portfolios (the distribution of patents across technological fields) indicate a better fit with the technological portfolios of LPTCs than with those of local universities. This tendency is salient for manufacturing LPTCs. Second, LPTCs collaborate more intensively on research with local SMEs compared to the local universities. This tendency is also salient for manufacturing LPTCs. Third, in regions where SMEs' technological portfolios are concentrated in biotechnology, LPTCs engage more in licensing. In regions where SMEs' technological portfolios are concentrated in mechanical engineering, LPTCs engage more in technical consultation.

Keywords: Innovation, Patents, Regional innovation systems, Sectoral innovation systems, Small- and medium-sized enterprises, Spillover, Japan

JEL classification: D83; L26; M13; O31; O32; O33

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1. Introduction

Local public technology centers (LPTCs) are a regional innovation policy unique to Japan. LPTCs, established by local authorities, aim to enhance the technological capabilities of local small- and medium-sized enterprises (SMEs) through technology transfer. LPTCs were first established to improve productivity in the agriculture industry in the late 19th century and have been augmented in terms of both geographical and technological coverage throughout the 20th century (see Appendix Figure 1.). LPTCs currently engage in technological support for SMEs in all prefectures and in various types of technologies, such as manufacturing, agriculture, environment and public health, and medicine. Some LPTCs are devoted to specific technologies, such as brewery, ceramics, and textiles, based on the type and size of demand for public technological services, reflecting the natural, industrial, and historical background of the region. The technological support LPTCs offer SMEs includes testing of raw materials and final products, technical consultation, seminars for the diffusion of new technologies, and open laboratories for SMEs that cannot afford experimental facilities. Furthermore, LPTCs conduct their own research, patent research outcomes, and license out their patented technologies, mainly to local SMEs. They engage in joint research and accept funded research from firms. LPTCs also act as a mediator that connects SMEs that lack social capital with other external sources knowledge, such as universities.

Since the 2000s, LPTCs have been faced with two structural changes that have made them redefine their roles in regional innovation systems. First, the prolonged economic stagnation after the 1990s has left local authorities in serious financial difficulties. Furthermore, as a result of the government's structural reform in the 2000s, local authorities have had their subsidies reduced substantially. Consequently, local authorities reduced the budgets of LPTCs and started to rigorously evaluate their contribution to the regional economy. Second, the national innovation system was fundamentally reformed after the late 1990s. This was symbolized by the enactment of the National University Corporation Law in 2004, which incorporated national universities. National universities, ex-imperial universities in particular, used to be a main source of knowledge for innovative large firms. The series of reforms required national universities in a region to share their knowledge with local SMEs, whereas before the reforms, national universities were not strongly motivated to become involved in regional economies. This change marked the national universities' entry into local markets for public technological services, initially dominated by LPTCs.

Under these circumstances, LPTCs were required to clarify their roles in regional innovation systems to better function as a part of the regional innovation policy. However, lack of comprehensive data and previous quantitative evaluation of the effectiveness of their technology transfer activities made it difficult for them to rebuild their strategies based on evidence. Using comprehensive databases on patents and LPTCs, this study quantitatively evaluates the roles played by LPTCs in regional and sectoral innovation systems.

Specifically, this study explores the following research questions. First, this study examines the different roles LPTCs and universities play in regional innovation systems. LPTCs are expected to help local SMEs improve productivity. Therefore, local SMEs' technological portfolios (the distribution of patents across technological fields) are predicted to indicate a better fit with the technological portfolios of LPTCs than with those of local universities. Second, this study investigates whether LPTC joint patents (patents that include both a firm researcher and an LPTC researcher as inventors) act as a conduit of regional knowledge spillover. Joint patents are used to represent research collaborations between LPTCs and firms. This study examines how LPTCs' research networks are localized and which type of firms LPTCs are likely to collaborate with. Furthermore, using the examination data, this study evaluates how joint patents between LPTCs and the collaborating firms are developed. Third, this study examines how LPTCs arrange channels for technology transfer based on the characteristics of the sectoral innovation systems. The concept of sectoral innovation systems highlights the significant variation in the creation and diffusion of knowledge across sectors. According to this framework, in regions where SMEs more actively innovate in biotechnology, for example, LPTCs are predicted to engage more in licensing because patents are very effective as a means of appropriation and dissemination of analytical knowledge, which innovative activities in the biotechnology-related industry tend to build on. On the other hand, in regions where SMEs innovate more actively in mechanical engineering, LPTCs are predicted to engage more in technical consultation because face-to-face communications are required for efficient transfer of synthetic knowledge, which innovative activities in the engineering fields tend to build on.

The remainder of this paper is organized as follows. Section 2 reviews previous literature on regional and sectoral innovation systems and proposes hypotheses according to three research questions. Section 3 describes how the dataset is constructed and how each concept used in the hypotheses is measured. Section 4 shows empirical results, and their theoretical and practical implications are discussed in Section 5. Section 6 summarizes the key findings and refers to agendas for future research.

2. Hypotheses

Knowledge creation by LPTCs in regional innovation systems

Previous studies have provided two significant frameworks for evaluating how knowledge is created and disseminated: regional innovation systems and sectoral innovation systems. The concept of regional innovation systems originally comes from the idea of national innovation systems, highlighting interactions rather than independent efforts among industry, universities, public research institutes, and government in the creation and dissemination of knowledge (Lundvall et al. 1992; Nelson et al. 1993; Braczyk et al. 1998). According to the framework of national innovation systems, fostering spillover from public knowledge, such as university research, is a key to promoting industrial innovations as well as strengthening the research capabilities of the private sector.

In the framework of regional innovation systems, the key concept is the localized flow of knowledge. As far as public channels, like publications, are concerned, the geographical range of knowledge spillover is not deemed to be localized. However, a number of empirical studies show that knowledge spillover is geographically constrained (Jaffe 1989; Mansfield 1995; Audretsch and Feldman 1996; Anselin et al. 1997; Autant-Bernard 2001; Acs et al. 2002; Gittelman 2007; Ponds et al. 2010). The key reason behind this is that some technologies in their embryonic stage consist of tacit knowledge that requires face-to-face communications for efficient transfer, which prefers geographical proximity. This implies that a region becomes a key unit of analysis in knowledge creation and dissemination.

Technology transfer activities of LPTCs are embedded in the region as most of their clients are local SMEs. On the other hand, rather than develop regional linkages to SMEs that seek out solutions to immediate problems, universities tend to develop global research networks with major actors in sectoral innovation systems like multi-national enterprises (MNEs) that aim to build long-term capabilities. Therefore, LPTCs' technological portfolios, defined as the distribution of patents across technological fields, are predicted to show greater similarity to those of local SMEs compared to local universities. As most of the LPTCs are established by prefectures, this study takes a prefecture as the geographical unit of analysis. Based on these discussions, two hypotheses are derived about the different roles played by LPTCs and universities in regional innovation systems.

H1a: The similarity of technological portfolios between LPTCs and SMEs in a prefecture is greater than that between universities and SMEs in the prefecture.

H1b: The similarity of technological portfolios between LPTCs and large firms in a prefecture is smaller than that between universities and large firms in the prefecture.

Knowledge dissemination by LPTCs in regional innovation systems

LPTCs were established and developed as a part of a regional innovation policy of local authorities. Therefore, they are supposed to make greater commitments to regional development than universities in the region. LPTCs conduct joint research with firms, which sometimes leads to joint inventions, and some of the joint inventions are patented. This study defines LPTC joint patents as patents that include both a firm researcher and an LPTC researcher as inventors whether the patents are owned jointly with collaborating firms or not. In light of the roles LPTCs are expected to play in regional innovation systems, LPTC joint patents are predicted to include more local and small collaborating firms than university joint patents. Therefore, it is hypothesized that:

H2a: LPTC joint patents have more local SMEs as collaborators than university joint patents.

From a legal perspective, some consider that university-industry joint research acted as a means for large firms to preempt outcomes of publicly funded research (Kneller 2007). Unlike US Patent Law, Japan Patent Law (Article 73) does not allow a co-owner (in this case the university) to transfer or license jointly owned patents to other firms without the permission of the other co-owners (in this case the industry partners). This legal environment could offer large firms an advantage to preempt the outcomes of university research through joint research. Under such circumstances, the industry partner may not intend to use a joint patent internally, and may exploit joint research for a strategic purpose, such as blocking competitors. Historically, it has been ex-imperial universities (a select number of national universities) that have accumulated a significant proportion of academic knowledge and it has been large firms that have maintained close relationships with such prestigious national universities. Therefore, preemption could deteriorate social welfare in terms of the efficient diffusion of outcomes from publicly funded research.

These arguments suggest the absence of knowledge spillover in university-industry collaborations rather than the acquisition of complementary knowledge from academic research. Regarding technology transfer activities of LPTCs, their research collaborators are mostly local SMEs. Empirical studies indicate great variations in patent strategies by firm size. Specifically, the strategic use of patents, such as preempting substitute technologies to prevent competitors from patenting them, is typically observed in large firms, while SMEs tend to use patents for internal use (Giuri et al. 2005; Nagaoka and Walsh 2009). As patenting is costly for SMEs with limited resources, they patent only when they see commercial potential in the patented technology. Therefore, it is possible that university joint patents are used as a means of preemption by large firms, while collaborators with LPTCs are keen to commercialize joint patents and have little incentive to use joint patents to block competitors.

In this regard, the examination of joint patents could be used to quantify such strategic use of patents by the collaborators of LTPCs and universities. The unexamined joint patents suggest that these firms were uninterested in commercialization of the joint patents, but did not want other firms to patent it. Conversely, the examination of joint patents suggests firms' ongoing interest in further development of the joint patents. Based on these discussions, the following can be hypothesized to measure knowledge spillover to (or preemption by) collaborating firms through their research collaborations with LPTCs and universities.

H2b: LPTC joint patents are more likely to be examined than university joint patents.

Technology transfer activities by LPTCs in sectoral innovation systems

Another theoretical framework to analyze the creation and diffusion of knowledge is the concept of sectoral innovation systems. Previous studies on sectoral innovation systems highlight that industrial innovations exhibit distinct sectoral patterns in terms of technological opportunities, appropriability conditions, and spillover channels (Nelson and Winter 1982; Pavitt 1984; Malerba 2002). First, firms innovate not only by exploiting internal resources, but also by using external sources of knowledge, such as feedback from customers, better input from suppliers, reverse engineering of competitors' products, and academic research by universities and public research institutes. It has been recognized that different sectors rely on different external sources of knowledge. Specifically, impacts of academic research on industrial innovations are the greatest in the pharmaceuticals where advancement in life sciences directly boosts drug discovery (Hicks et al., 2001; Huang and Murray, 2009; Furman and Stern, 2011). Second, previous innovation surveys conducted in various countries show that the effectiveness of patents as a means to significantly appropriate the returns to R&D investment varies across industries, which leads to significant variations in patent propensity at the industry level (Levin et al. 1984; Arundel et al. 1995; Goto and Nagata 1997; Cohen et al. 2000; Nagaoka and Walsh 2009). Specifically, patents are the most effective in biotechnology. Biotechnology innovations tend to be standalone as opposed to systemic in that a final product can be clearly defined by specific information in patent documents (e.g., chemical equations), which makes it very difficult for followers to invent around, and makes patents particularly effective as appropriation mechanisms for innovators. Third, previous studies on industrial knowledge bases classify economic activities into three broad categories: analytic (science), synthetic (technology), and symbolic (culture), and argue that different industrial knowledge bases require different modes of transfer in a systematic manner (Asheim and Gertler 2005; Asheim et al. 2007; Martin and Moodysson 2011).

Specifically, previous studies on industrial knowledge bases consider the degree to which tacit knowledge is involved and the significance of personal interactions in knowledge transfer as key components of this framework. First, innovations in science-based sectors, like biotechnology, tend to build on analytical knowledge that can be defined as the knowledge to understand and explain features of the universe (Asheim and Gertler 2005). The production of analytical knowledge refers to encapsulating natural sciences and mathematics where key inputs are the review of scientific articles and the application of scientific principles. Knowledge outputs can be communicated in a universal language like mathematical or chemical equations, which are the least tacit and the most likely to be embodied in codified channels (e.g., scientific articles and patents). Therefore, they tend to be disseminated through channels without geographical constraints like licensing. Second, innovations in mechanical engineering tend to build on synthetic knowledge that can be defined as knowledge to design something that works as a solution to a practical and more applied problem. Knowledge is created through a heuristic approach (i.e., learning by doing) rather than a deductive process, which makes know how and craft-based skills, both contain more tacit knowledge, more important for innovations of this type. Efficient transfer of tacit knowledge requires face-to-face communications among scientists and engineers, which tend to be more active in industrial clusters (Storper and Venables 2004). Therefore, innovations based on synthetic knowledge tend to be disseminated through personal interactions like technical consultation, which prefers geographical proximity. Third, the production of symbolic knowledge refers to the creation of cultural meanings embodied in shapes, images, words, sounds, experiences, and cultural artifacts. Symbolic knowledge is the most tacit because the means of production is based on learning by doing and observing other creators including artists, musicians, product designers and architects. These characteristics strongly affect the spatial configurations of talents because the nature of valuable knowledge in such occupations particularly prefers the spatial concentration of talents, facilitating frequent personal interactions. This implies that talents located in a cluster would be able to receive greater spillover of locally embedded knowledge from other talents through personal interactions, making them more productive (Gertler 2003; Tether et al. 2012).

Therefore, types of innovations dominant in a region would affect the channels for technology transfer that LPTCs should arrange. Considering most of the users of LPTC technology transfer are local SMEs, characteristics of regional innovations should be captured as those of small firm innovations. Based on these discussions, two hypotheses are derived about the different modes of knowledge transfer from LPTCs according to sectoral innovation systems.

H3a: In a prefecture where SMEs' innovative activities concentrate in biotechnology, LPTCs tend to engage in licensing.

H3b: In a prefecture where SMEs' innovative activities concentrate in mechanical engineering, LPTCs tend to engage in technical consultation.

3. Method

Identification of size of patent applicants

This study gathers data from the Institute of Intellectual Property Patent Database (IIPPD). IIP is an external body of the Japan Patent Office (JPO) and compiles a publicly available database of all the patents applied for at the JPO (Goto and Motohashi 2007). The data collected for the analysis were released in May 2014. This study uses information on patents applied for at the JPO from 2000 to 2009. The patent application year is used as not all the patents filed are registered. This empirical period was selected because patent information has to be matched with another database on LPTCs' technology transfer activities available from 2000 to 2009.

In order to identify applicant firm size, this study employs data from the National Institute of Science and Technology Policy Corporate Database (NCD), released in November 2014. NCD employs the following definition from the SME Basic Law to identify firm size: large firms, SMEs, and micro-businesses. Micro-businesses in the manufacturing sector are firms that employ less than 21 workers. SMEs are firms that employ less than 301 workers or are capitalized at equal to or less than 300 million yen. Large firms are those that employ more than 300 employees or are capitalized at more than 300 million yen. The threshold applied varies across sectors. Micro-businesses are integrated into SMEs in the empirical analysis. NCD collects information about all firms that filed at least 100 patents from 1970 to 2010 and all the listed firms regardless of the number of patents filed. Therefore, only SMEs that are listed or applied for more than 99 patents are identifiable from NCD. IIPPD, matched with NCD, contains 3,701,258 patents of which 4.8% were filed by SMEs and 67.8% were filed by large firms. This means that 27.4% of the applicants, that is, unlisted firms that filed less than 100 patents from 1970 to 2010, were not identifiable using NCD. In this regard, previous studies employed a threshold, as a rule of thumb, of 100 patents to identify small-sized applicants (Motohashi and Muramatsu 2012; Galasso and Schankerman 2014). In light of the definition of SMEs by NCD, this study assumed that applicants unidentifiable from NCD that filed less than 100 patents from 2000 to 2009 were SMEs.

It should be noted that firm size is identified using information as of 2014 and it was not possible to identify firm size in the empirical period of this study. Therefore, it is possible that firms that were SMEs in the empirical period are identified as large firms based on information as of 2014. This would make the sample biased to large firms, leading to the underestimation of the presence of SMEs in the analysis.

Identification of technological fields

As this study employs patent data to test hypotheses on sectoral innovation systems, it is important to match patent classification and industrial classification. This study employs IPC technology concordance (IPC8) to identify six technological fields, including instruments, mechanical engineering, electrical engineering, chemistry excluding biotechnology, biotechnology including pharmaceuticals, food engineering, environment technology, and others. IPC8 identifies five sectors with chemistry including biotechnology. In order to analyze biotechnology separately, this study extracted biotechnology from chemistry. Appendix Table 1 lists sample technologies in each field, which were extracted from IPC8 Technology Concordance Table.

Identification of the location of innovations

The geographical unit of analysis is a prefecture, which is a local unit of governance in Japan. There are 47 prefectures. An average prefecture is approximately 8,000 sq km, which is even smaller than an average state in the US (approximately 196,500 sq km) and larger than an average department in metropolitan France (approximately 5,700 sq km). This study identifies the location of the innovation at the level of the inventors rather than the applicants. If the location of innovation is identified at the level of applicant address, innovations at large firms would be overly concentrated in Tokyo and Osaka where most of the large firms' headquarters are located. Regarding university patents, before the incorporation of national universities in 2004, patents invented by national universities were filed by a nation or an individual. This makes it difficult to identify the location of innovation from an applicant address because of the unavailability of information on the home addresses of the university inventors. Regarding LPTC patents, most of LPTCs do not exist as legal entities (they are one of the divisions of local authorities.), which means that the local authorities apply for the patents invented by LPTCs. It is, however, not possible to assume that all the patents filed by local authorities are created by LPTCs because local authorities have other divisions, such as public universities, that may create patentable technologies. Therefore, this study uses inventor addresses to identify patents created by LPTCs.

Regarding the first research question, this study compares the similarity of technological portfolios of LPTCs and universities in a prefecture to those of SMEs and large firms in the prefecture. The actual process to identify the location of innovation for each constituency of a regional innovation system can be summarized as follows. First, large firms tend to have a policy that requires inventors to indicate the headquarters of the firm as the inventor address, instead of the home address of the inventors or the research laboratory of the firm. Therefore, for firms with such a policy, this study assumes that the headquarters and the research laboratory of the firm are located in the same prefecture. For firms without such a policy, this study assumes that the home of the inventor and the research laboratory are located in the same prefecture, which means that inventors are not commuting beyond prefectures. Based on these assumptions, this study identifies the location of invention as a prefecture indicated in the inventor address that includes the name of the firm. It should be noted that if the inventor gives just an office address, without the name of the firm he or she works for, it is not possible to identify the location of innovation. The same caveat applies to the cases of universities and LPTCs.

Second, SMEs normally do not to have a policy about how inventors indicate their addresses in patent documents. Even though SMEs require inventors to indicate their headquarters, it is unlikely for SMEs to have a headquarters and a research laboratory in different prefectures. Furthermore, it is unlikely for SME employees to commute beyond the border of the prefecture. Therefore, this study identifies the location of SMEs' invention as the prefecture indicated in the inventor address that includes the name of the firm.

Third, university inventors could indicate either their home or university as the inventor address.[2] It is not possible, however, to collect information for all the university inventors' home addresses. Only when the university inventors indicate their homes within the site of the university (e.g., a university residence which includes the name of the university) it is possible to identify the location of university inventions. Based on these assumptions, this study identifies the location of invention as the prefecture indicated in the inventor address that includes the name of the university with which the inventor is affiliated.

Fourth, LPTC inventors could also indicate either their home or LPTC as the inventor address. For the same reason as with SMEs' inventions, this study identifies the location of invention as the

2 Universities in this study include national, public, and private universities with departments in natural sciences, medicine, and technology.

prefecture indicated in the inventor address that includes the name of LPTC.

Similarity between technological portfolios

The similarity of the technological portfolios of LPTCs and universities in a prefecture to those of SMEs and large firms in the prefecture is measured using the cosine similarity which can be defined as $\cos\vartheta = \frac{X \cdot Y}{|X||Y|}$ where a vector *Xij* denotes LPTCs' patents (or universities' patents) in a prefecture *i* and a technological field *j* while another vector *Yij* denotes SMEs' patents (or large firms' patents) in *i* and *j* (*j*=1…6). The cosine similarity was calculated by prefecture. This index captures how the portfolios of technological resources of large firms, SMEs, universities, and LPTCs are similar to one another. For instance, if most of the universities in a prefecture specialize in life sciences, while most of the local SMEs are engaged in the machinery industry, the similarity between universities and the SMEs in the prefecture will be very small.

Joint patents, joint application, and solo application

To address the second research question, this study quantifies the localization of knowledge networks of LPTCs and universities as follows. The research collaborations of LPTCs and universities with firms may yield joint inventions, some of which will be filed jointly with collaborating firms. It is also possible that outcomes of joint research will be transferred voluntarily to the collaborating firms in return for donations. This used to be common in collaborations between research universities and large firms before the national innovation system reform in Japan (Odagiri 1999; Yoshihara and Tamai 1999; Fukugawa forthcoming). "Joint patent" means a patent that includes both a firm researcher and an LPTC researcher (or a university scientist) as inventors.[3] Therefore, this study uses the term "joint patents" to mean "joint inventions". "Joint application" means a patent application that includes both a firm and an LPTC (or a university) as applicants. Even though a firm and a public research institute jointly invent a new technology, it is possible that the technology is patented solely by the firm, which is defined as "solo application" of a joint patent. Joint patents represent research networks of LPTCs and universities. This study captures the characteristics of research networks, such as the type of recipients of spillover (i.e., SMEs and large firms) and localization of knowledge networks (i.e., collaborating firms being located in the same prefecture with LPTCs or universities). The proportion of SMEs to joint patents measures the type of

[3] Motohashi and Muramatsu (2012) considered (in the case of applicant/year of application samples having more than 10 patent applications) the proportion of patents with personal and corporate addresses plus the proportion of patents with corporate and public university addresses to be the proportion of jointly invented university-industry patents for samples in which corporate-address-only patents account for 50% or more. Although this would be a systematic approach to correct bias stemming from unidentified university inventors who indicate home addresses in the inventor address, this study did not adopt the approach because of very low regression coefficients of the share of individual and corporate patents against the share of corporate and public university patents.

recipient of knowledge spillover. The proportion of locally collaborating firms to joint patents measures the localization of research networks.

Some joint patents could be left unexamined because collaborating firms are uninterested in commercialization and simply do not want other firms to patent the technology. Thus, it is considered that the proportion of examined patents to joint patents represents firms' ongoing interest in further development of the joint patent. This index is used to examine **H2b**.

Last, this study measures the technological and commercial value of LPTC patents and university patents in the following way. The number of claims represents novelty, and thus is considered to represent the technological value of patents (Gambardella et al. 2008). Citations added by patent examiners are indicative of the exclusionary value of patents in that the patent is cited by a patent examiner mainly to eliminate subsequent patent applications (Suzuki et al. 2015).[4] Therefore, examiner forward citations are considered to represent the commercial value of patents.[5] The propensity of patents to be filed via the Patent Cooperation Treaty (PCT) is considered to represent the commercial value of the patents because inventions with higher commercial value are more likely to be patented globally (Putnam 1996).

Identification of industrial agglomerations

Regarding the third research question, I computed correlation coefficients between LPTCs' technology transfer channels and the specialization index of local SMEs' innovative activities. The specialization index is measured by location quotient, $LQ=(X/Y)/(X'/Y')$. X is the number of patents filed in a specific technological field, and in a specific prefecture. Y is the number of patents filed in the prefecture. X' is the number of patents filed in the technological field, and in Japan. Y' is the number of patents filed in Japan. LQ was calculated by technological field. The more specialized the innovative activities are in a specific technological field, the greater the location quotient of that technological field. For instance, if the innovative activities of local SMEs are concentrated more in drug discovery than the population mean, the location quotient of the prefecture will be the highest in

4 Forward self-citation is the case where an applicant of a citing patent and that of a cited patent are identical. Forward citations other than forward self-citations are regarded as forward non self-citations. As described earlier, cited patents are patents applied for at the JPO from 2000 to 2009, while citing patents are those filed by 2012, which is the last year available from IIPPD as of 2014. Truncation is salient after 2009, the year in which a drastic decrease (from 16% share in 2008 to 10% in 2009) in forward citations is observed. Citing patents filed between 2010 and 2012 account for 8.7% of the total forward citations.

5 IIPPD (released in May 2014) exclusively collects information of citations added by patent examiners. This means that forward non self-citations in this study represent the commercial (exclusionary) value of patents (Suzuki et al. 2015). Unlike examiner forward citations, inventor forward non self-citations represent a far-reaching impact of the patent on the economy, and thus patent quality (Hall et al. 2005). However, information for this variable was not available due to the data constraint.

biotechnology.

Technology transfer channels

In order to quantify technology transfer activities of LPTCs, this study uses "Current Status of LPTCs: 2000-2009" compiled by the National Institute of Advanced Industrial Science and Technology (AIST). This database provides information on the number of researchers with doctoral degrees, testing, open laboratories, workshops for the diffusion of new technologies, technical consultation, funded research projects, joint research projects, licensed patents, and scientific publications. This database also provides information on revenues from licensing and funded research. All the variables are divided by the number of researchers to control for the size of LPTCs. The average from 2000 to 2009 was used for analysis. Descriptive statistics are provided in Appendix Table 2. The Spearman rank-order correlation coefficient was computed as these variables were not normally distributed.

4. Results

Knowledge creation by LPTCs in regional innovation systems

Regarding the first research question, Table 1 shows the differences between patents held by LPTCs and universities. The unit of analysis is a prefecture and the number of observations is 47. First, Panel A of Table 1 shows that the cosine similarity between LPTCs and SMEs is 0.770, while the cosine similarity between universities and SMEs is 0.705. According to a t-test, there is a statistically significant difference between the two (p=0.002), which lends support to **H1a**. Second, the cosine similarity between LPTCs and large firms is 0.695, while the cosine similarity between universities and large firms is 0.722. Although this appears to support the prediction, the difference between the two is statistically insignificant (p=0.348), which means that **H1b** is not supported.

Knowledge dissemination of LPTCs in regional innovation systems

Regarding the second research question, Table 1 shows the differences in joint patents between LPTCs and universities. First, Panel A of Table 1 shows that there is no statistically significant difference in the probability of collaboration with firms between LPTCs and universities. However, second, LPTCs do engage more than universities in localized collaborations and this difference is statistically significant. Furthermore, the probability of LPTCs' collaborating with local SMEs is even higher than that of universities, which lends support to **H2a**. Third, Panel B of Table 1 shows that the probability that joint patents are examined is not different between LPTCs and universities. Furthermore, in order to control for the effect stemming from the difference between LPTCs and universities in potential collaborator firm size, I performed the same test for a subsample of local SMEs. The difference between the two is still insignificant, although LPTCs show a higher ratio than universities in the region. Thus, **H2b** is not supported. Fourth, the voluntary transfer of academic inventions to large firms that have informal connections to university scientists used be a key route of university-industry collaborations before the national innovation system reform after the late 1990s that promoted contract-based modes of university-industry collaborations (Odagiri 1999; Yoshihara and Tamai 1999; Fukugawa forthcoming). This suggests that the probability of joint patents' being filed solely by firms is higher among university joint patents. However, there is no significant difference between universities and LPTCs. Fifth, Panel C of Table 1 shows that LPTC patents receive more examiner forward citations, which means that they have a higher commercial value in that they are cited to prevent subsequent patent application by others (Suzuki et al. 2015). Sixth, university joint patents tend to be filed internationally, which also suggests a higher commercial value for university joint patents rather than LPTC joint patents (Putnam 1996). Seventh, university joint patents tend to have more claims than LPTC joint patents, which suggests a higher technological value for university joint patents than for LPTC joint patents (Gambardella et al. 2008).

Table 1 here

In order to understand characteristics of knowledge creation by LPTCs in depth, I compare LPTCs engaged in four areas: manufacturing, agriculture, environment and public health, and medicine. Table 2 shows the results. The unit of analysis is an LPTC and the number of observations is 293.

Panel A of Table 2 shows a statistically significant difference across types of LPTCs in the key technology they engage in. First, LPTCs in manufacturing focus on chemistry and mechanical engineering. They exhibit a more balanced allocation of research efforts in each technological field than other types of LPTCs, which is consistent with previous findings (Japan Association for the Advancement of Research Cooperation 2011).[6] Second, knowledge creation of agricultural LPTCs is concentrated in mechanical engineering because these LPTCs tend to engage in the development of agricultural equipment, such as harvesters and sprayers. They also develop agricultural materials, such as yeast and enzymes, which explains the high concentration of their knowledge production in biotechnology (Nikkei 2014). Third, it is reasonable to see that patents of medical LPTCs are exclusively concentrated in biotechnology. Fourth, LPTCs in environment and public health tend to focus on research in biotechnology, although they are also intensively engaged in research in chemistry.

Panel B of Table 2 shows characteristics of knowledge creation and dissemination by LPTCs according to the areas they specialize in. First, technological portfolios of manufacturing LPTCs exhibit the highest cosine similarity with those of local SMEs. This suggests that it is manufacturing LPTCs that possess technological knowledge in the most regionally adapted manner. Second,

[6] According to this survey, the efforts of the researchers at manufacturing LPTCs have been allocated as follows: to research 35%, to technical assistance based on personal interactions (e.g., technical consultation) 27%, and based on physical assets (e.g., testing) 24%. The distribution of efforts was 63%, 20%, and 7%, respectively, at agricultural LPTCs, and 30%, 8%, 52%, respectively, at environment and public health LPTCs.

manufacturing LPTCs collaborate with local SMEs most intensively (the third column). This implies that manufacturing LPTCs are the most committed to regional economic development, which is consistent with the fact that they are most engaged in technical consultation (as indicated in Panel C of Table 2), which requires personal interactions with clients. Third, manufacturing LPTC joint patents are the most likely to be examined, which suggests collaborating firms are interested in further development of joint inventions rather than simply making the joint invention public in order to prevent other firms from patenting it. This is consistent with the previous finding that manufacturing LPTCs are the most committed to regional economic development. Fourth, it is medical LPTCs that create knowledge with higher commercial value in terms of examiner forward citations. Indeed, a recent survey shows that a medical LPTC received the largest amount of royalties among all LPTCs in 2012 (Nikkei 2014). This underscores the fact that they engage in the development of research tools that are widely used in downstream research in medicine. Fifth, PCT (Patent Cooperation Treaty) applications are the most salient among the patents of medical LPTCs, which enhances the finding that medical LPTCs create knowledge with higher commercial value. Another interpretation is that the choice of a PCT application could be affected by sectoral patterns of innovation. In industries characterized by standalone innovations like drugs, the commercial potential of innovation is inherently global, which leads to the greater probability of choosing a PCT application. Sixth, medical LPTCs record the largest number of claims. As shown in Panel A of Table 2, medical LPTCs focus on biotechnology where innovation is standalone and consists of a smaller number of technological elements. This suggests a smaller number of claims of medical LPTC patents. One interpretation is that medical LPTCs intensively engage in research on precision instruments (as shown in Panel A of Table 2) where innovation is systemic and consists of a greater number of technological elements, which may have resulted in the largest number of claims.

Panel C of Table 2 shows how technology transfer channels vary according to types of LPTCs. Testing of final products and raw materials is more prevalent among manufacturing LPTCs and environment and public health LPTCs, while it is rare for agricultural LPTCs. This stems from the fact that environment and public health LPTCs typically engage in research on measurements and standards, which means that testing is their major channel for technology transfer. Firms' use of analytical equipment and experimental facilities is widespread among medical LPTCs and manufacturing LPTCs, while it is rare for environment and public health LPTCs. Manufacturing LPTCs engage in technical consultation most actively. This is consistent with the finding that they are most likely to collaborate with local SMEs, and with the fact that technical consultation is the channel that most requires personal interactions and geographical proximity. LPTCs in agriculture and manufacturing hold more seminars for technology diffusion, while it is rare in environment and public health LPTCs, though the difference among groups is not statistically significant. Revenue from funded research and licensing is the highest for manufacturing LPTCs, while the difference among groups is not statistically significant. Royalties from medical LPTCs are recorded as zero because royalties of those LPTCs were not included in the AIST database of LPTCs' technology transfer activities. Joint research is the most active among manufacturing LPTCs, which is consistent with the finding that they actively collaborate on research with firms. Researchers at agricultural LPTCs are the most productive in terms of scientific publications even though the ratio of Ph.D. researchers is the lowest. In contrast, medical LPTCs record the highest ratio of Ph.D. researchers, while scientific productivity in terms of publications per researcher is the lowest.

Table 2 here

Technology transfer activities by LPTCs in sectoral innovation systems

In order to address the third research question, I examined statistical relationships between LPTC technology transfer channels and technological specialization local SMEs exhibit. Table 3 shows the Spearman rank-order correlation coefficients between LPTC technology transfer channels and location quotients of SMEs in the region. First, in regions where innovative activities of SMEs concentrate in the field of biotechnology, LPTCs tend to engage in licensing, represented as royalties per researcher, which lends support to **H3a**. The result is consistent with the notion of sectoral innovation systems that the transfer of analytical knowledge prefers codified channels of transfer, such as licensing. Meanwhile, in regions where innovative activities of SMEs concentrate in the field of mechanical engineering, LPTCs are predicted to engaged less in licensing, which is also supported in the results. Second, in regions where innovative activities of SMEs concentrate in the field of mechanical engineering, LPTCs engage more in technical consultation that contains a greater extent of personal interactions, which lends support to **H3b**. Meanwhile, in regions where research activities of SMEs concentrate in biotechnology, LPTCs are predicted to engage less in technical consultation, which is also observed in Table 3.

Table 3 here

The relationship between technology transfer activities and outcomes

Table 4 shows correlation coefficients among LPTCs' technology transfer channels. First, the results show high correlation among testing, open laboratories, and technical consultation. These have been regarded as the most important channels for LPTCs to help SMEs improve their absorptive capacities. The result lends support to such a notion. Second, technical consultation is positively correlated with royalties, but not with revenue from funded research. Third, the number of Ph.D. researchers is positively associated with royalties and funded research, but not with technical consultation. Fourth, the number of scientific articles authored by LPTC researchers is negatively correlated with technical consultation and positively correlated with funded research. These results suggest that funded research that requires little interaction with clients does require that LPTC researchers have strong academic backgrounds, represented by doctoral degrees and publication of scientific articles. These factors would signal the high research quality of LPTCs, attracting potential clients and convincing clients that the outcomes will be as expected. On the other hand, not only a scientific basis, but also an understanding of SMEs' technological needs captured through technical consultation is needed for the commercial success of licensing patents. Fifth, joint research does not show significant correlation with technical consultation. This suggests that it is rare for technical consultation to develop into joint research (Fukugawa and Goto forthcoming).

Table 4 here

Summary of the results

The key findings from the empirical analysis can be summarized as follows. First, SMEs' technological portfolios indicate a better fit with the technological portfolios of LPTCs than with those of local universities. This tendency is salient for manufacturing LPTCs. Second, LPTCs collaborate on research with local SMEs more extensively compared to the local universities. This tendency is also salient for manufacturing LPTCs. Third, knowledge creation by manufacturing LPTCs ranges broadly, while other types of LPTCs demonstrate distinct patterns. Agricultural LPTCs concentrate in biotechnology and mechanical engineering. Environment and public health LPTCs concentrate in biotechnology and chemistry. Medical LPTCs concentrate in biotechnology and instruments. Fourth, LPTC joint patents receive more examiner forward citations than university joint patents. This tendency is salient for medical LPTCs. Fifth, medical LPTCs create inventions with higher technological value, measured by the number of claims. Sixth, knowledge dissemination (technology transfer) by manufacturing LPTCs is concentrated in technical consultation. Agricultural LPTCs concentrate in the publication of scientific articles. Environment and public health LPTCs concentrate in testing. Medical LPTCs exhibit the highest ratio of researchers with doctoral degrees. Seventh, in regions where the technological portfolios of SMEs are concentrated in biotechnology, LPTCs engage more in licensing. In regions where the technological portfolios of SMEs are concentrated in mechanical engineering, LPTCs engage more in technical consultation. Eighth, royalties depend on both the number of problems solved through technical consultation and the ratio of Ph.D. researchers.

5. Discussion

Policy implication

This study should appeal not only to researchers interested in sectoral and regional innovation systems, but also to policymakers responsible for developing regional innovation policy. Panel A of Table 1 shows that LPTCs are more locally embedded than local universities. This is apparent in terms of both knowledge creation (**H1a**) and knowledge dissemination (**H2a**), and is good news for local authorities because LPTCs are the embodiment of a regional innovation policy to help local SMEs improve productivity. Furthermore, Table 2 shows that regional collaborations are particularly salient for manufacturing LPTCs that engage intensively in technical consultation, which requires extensive personal interactions. This implies that technical consultation by manufacturing LPTCs could yield not only direct outcomes, such as solutions to immediate problems SMEs face, but also indirect outcomes, such as quality improvements among the human resources of the clients. The latter could have a long-term impact on productivity and innovations, even in the absence of any direct effects.

Panel B of Table 2 shows that local embeddedness is particularly salient among manufacturing LPTCs that tend to engage in technology transfer in mechanical engineering. However, local embeddedness is not observed in medical LPTCs devoted to biotechnology. Table 3 shows that technical consultation is the key technology transfer channel in agglomerations of mechanical engineering, while licensing matters in biotechnology agglomerations. These results provide important policy implications regarding how LPTCs should develop technology transfer channels according to regional characteristics and technological specialization. The geographical coverage of LPTCs' technology transfer activities is bound by the type of transfer channel. On the one hand, the geographical range of technical consultation, which builds on personal interactions, is limited. Therefore, manufacturing LPTCs' technology transfer activities need to be locally embedded. On the other hand, licensing activities are less geographically constrained. This implies that LPTCs actively engaged in licensing could make technology transfer more efficient by expanding these activities beyond prefectural borders, thereby generating economies of scale through access to various potential licensees while spreading out the administrative cost (Lach and Schankerman 2008). This type of development strategy would be relevant for medical LPTCs which specialize in biotechnology and exhibit greater inclination to licensing. Furthermore, even in the same prefecture, there are normally several manufacturing LPTCs, reflecting diversified industrial agglomerations in the prefecture. Therefore, it is reasonable for manufacturing LPTCs that have an advantage in biotechnology (e.g., foods and brewery) and engage extensively in licensing to expand their technology transfer activities across prefectural borders by devising innovative budgeting.

Regarding manufacturing LPTCs, the results suggest that technical consultation is significant not only as a means of problem solving for clients, but also as a channel for further development of LPTC inventions (Fukugawa and Goto forthcoming). Table 4 shows that technical consultation is positively correlated with royalties, which is consistent with the findings of Fukugawa (2009). Interactions with SMEs through technical consultation foster an understanding among LPTC researchers of local SMEs' technological problems. This increases the probability of the commercial success of licensing because LPTC researchers have a clearer understanding of the local SMEs' technological needs and are more likely to generate valuable inventions that are readily commercialized by these SMEs. Furthermore, the commercial value of LPTC patents can be improved by strengthening the scientific basis of LPTC research as well. This suggests that the improvement of human resources, such as collaborations with universities encouraging LPTC researchers to gain a doctorate, would enhance spillover from LPTCs via licensing. In the course of completing their doctorates, LPTC researchers would also be able to expand their knowledge networks to various firms and university scientists, enabling them to help SMEs improve productivity not only by providing better solutions based on academic knowledge they acquired, but also by exploiting these knowledge networks and connecting SMEs with a broader source of knowledge in the future. This would also have a positive implication for the commercial success of LPTC inventions. It is notable that strengthening the scientific background of LPTC researchers and supporting SMEs through problem solving do not necessarily create a trade-off (as they may appear) because there is no significant negative correlation between the ratio of Ph.D. researchers and technical consultation (Table 4). This suggests that the two strategies could work together if LPTCs encourage researchers to complete their doctorates by having them select a research topic grounded in the technological needs of local industry.

Research implication

Technology diffusion programs to enhance the absorptive capacity of SMEs prevail in many developed countries as a part of regional innovation policy. Examples include Manufacturing Technology Centers (MTC) and Manufacturing Extension Partnerships (MEP) in the US (Jarmin 1999), TNO (the Netherlands Organisation for Applied Scientific Research), the Steinbeis Foundation in Germany, the Regional Board for Economic Development (ERVET) in Emilia-Romagna of Italy, and Technology Innovation Centres in the UK (Shapira and Rosenfeld 1996). This study adds statistical evidence from Japan to previous studies on such programs for SMEs. This is important because much effort has been invested into the analysis of university spillover (Kneller, 2007; Motohashi and Muramatsu 2012), whereas LPTCs as a source of public knowledge have received little attention from researchers.

In addition, this study contributes to the previous literature by devising methodology for regional innovation policy evaluation based on sectoral and regional innovation systems. Specifically, the assessment of regional innovation policy could greatly vary according to the perspectives employed by empirical studies. Based on a framework of regional innovation systems, Fukugawa (2008) examined the fit between regional characteristics (i.e., the proportion of local SMEs performing R&D and the proportion of joint research projects between local SMEs and universities) and technology transfer channels arranged by LPTCs, and found no significant correlation between the two, which is in contrast to the findings here (e.g., Panel A of Table 1). The difference in the empirical approach of Fukugawa (2008) and this study lies in the incorporation of technological or industrial characteristics by region. This study evaluated regional characteristics by technological field, captured as the cosine similarity between the technological portfolios of LPTCs and local firms, which Fukugawa (2008) could not quantify due to data constraints at that time. In other words, the fit between regional innovation policy and regional innovation systems was evaluated not only in terms of the regional innovation systems, but also in terms of the sectoral innovation systems. The results shown in Table 3 imply that LPTCs have arranged different types of spillover channels according to the types of industrial agglomerations (e.g., biotechnology and mechanical engineering), presumably resulting in improved technology transfer efficiency.

The quantitative evaluation of regional innovation policy that incorporates sectoral innovation systems is an important but understudied field. In a more general context, regional spillover from public knowledge, such as university research, has been addressed by a recent study based on sectoral innovation systems. Dornbusch and Brenner (2013) statistically examine how university spillover, measured as applications for academic patents by firms as a result of research collaborations, is affected by technological regimes (engineering, life sciences, etc.), types of recipient (i.e., SMEs and MNEs), cognitive distance (i.e., cosine similarity between universities' scientific resources and industrial technological resources), and geographical distance between universities and firms. They find that in the field of engineering built on synthetic knowledge, which requires personal interactions for efficient transfer, research collaborations between universities and SMEs are promoted when they are cognitively close, whereas such relationships cannot be observed in research collaborations between MNEs and universities. In light of their findings, it can be said that an evaluation of technology diffusion programs in regional innovation systems should incorporate sectoral innovation systems into the analytical framework because modes of technology diffusion are affected by the type of knowledge the technology is built on. Furthermore, such an efficient design of a technology diffusion program particularly matters for SMEs with limited absorptive capacity, very sensitive to technological fit, or cognitive proximity to external sources of knowledge.

The advanced methodology developed in this study could be applied to fill the research gap in another unexplored area: catching-up economies. Technology diffusion programs that help SMEs enhance their absorptive capacity are very important for catching-up economies, particularly where SMEs have a greater presence in the business ecosystem. In the catch-up phase, it is relatively easy for firms to identify benchmarks in R&D since they are unlikely to be at the leading edge of technological progress. This makes efficient technology diffusion more significant for economic growth than the exploration of entirely new knowledge. Furthermore, the improvement in productivity in the SME sector has positive implications for growth in big businesses as well, particularly in discrete process industries where SMEs could undertake a significant proportion of the production process, such as in the automotive industry. As I have mentioned, previous studies in this field have focused on cases in developed countries. One exception is a case study on innovation intermediaries in Thailand (Intarakumnerd and Chaoroenporn 2013). This study evaluates national research institutes and trade associations as innovation intermediaries that help actors in sectoral innovation systems innovate not only by linking them to external sources of knowledge, such as universities, but also by giving them practical or scientific advice (Howells 2006). The study stresses the differences in roles (e.g., problem solving and networking) played by different types (e.g., public and private) of intermediaries in different sectors (e.g., the resource-intensive frozen food industry dominated by SMEs and the science-based hard disk drive industry led by MNEs). More effort should be invested into the quantitative evaluation of technology diffusion programs for SMEs in catching-up economies as it is rare in this field. In so doing, the division of labor among different organizations engaged in technology diffusion should be taken account, as stressed by Intarakumnerd and Chaoroenporn (2013).

6. Conclusion

This study evaluated the creation and dissemination of knowledge by LPTCs from the perspectives of sectoral and regional innovations systems. Summarizing the key findings, knowledge creation by LPTCs fits better with the characteristics of regional innovation systems than that by local universities. This is particularly salient among manufacturing LPTCs. The geographical range of knowledge dissemination by LPTCs, measured by the location of LPTCs' co-inventors, is localized. This tendency is also salient for manufacturing LPTCs. Furthermore, LPTCs arrange channels for technology transfer based on the characteristics of sectoral innovation systems. For instance, in regions where innovative activities of SMEs are concentrated in mechanical engineering, LPTCs engage more in technical consultation. On the other hand, in regions where innovative activities of SMEs are concentrated in biotechnology, LPTCs engage more in licensing.

These findings imply that manufacturing LPTCs act as a significant external source of knowledge for local SMEs, which is consistent with the aim of this regional innovation policy. Furthermore, the results are consistent with theoretical predictions from sectoral innovation systems that the channels for knowledge dissemination vary significantly across industries, reflecting the nature of the industrial knowledge bases (e.g., analytical and synthetic knowledge) and the significance of personal interactions in knowledge spillover. The policy implication here is that LPTCs' development strategies should consider complementary relationships between industrial agglomerations and technology transfer channels so that their activities are relevant for the local SMEs they aim to help. Last, the results imply that, for LPTCs to successfully commercialize their inventions, it is important to balance improving their scientific basis while engaging in problem solving with local SMEs, which may appear opposing efforts (Fukugawa and Goto forthcoming).

This study contributes to the previous literature not only by providing statistical evidence on LPTCs as a technology diffusion program for SMEs, but also by deriving methodological insights by incorporating the perspective of sectoral innovation systems into the analytical assessment framework of regional innovation policy. The advanced methodology developed in this study could be applied to unexplored area like catching-up economies.

The strength of this study lies in the use of patent data that allowed quantitative evaluation of regional innovation policy from the perspective of the sectoral innovation system, thereby engendering different insights from studies exclusively built on the analytical framework of regional innovation systems. However, this places constraints on the interpretation of the results as well. Most innovative attempts are doomed to fail, thus are unpatented. Furthermore, the effectiveness of patents greatly varies across sectors and patent propensity greatly varies according to sectors and firm size, which means that not all inventions are patented. Aside from such general caveats on the use of patents as a performance index, in the context of the evaluation of LPTCs, it should be noted that patenting cannot be viewed as the major technology transfer activities of LPTCs. A majority of their efforts have been allocated to activities like technical consultation, where outcomes are hard to define and measure quantitatively. Future research should collect qualitative information about such technology transfer channels through questionnaire surveys.

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Table 1 Test of difference between LPTC patents and university patents

Panel A	Similarity to technological portfolios of local SMEs** (**H1a**)	Similarity to technological portfolios of large local firms (**H1b**)	Joint patents/total	Joint patents with local firms/joint patents**	Joint patents with local SMEs/joint patents** (**H2a**)
LPTC	0.770	0.695	0.515	0.595	0.195
University	0.705	0.722	0.482	0.274	0.041

Panel B	Examined patents/total	Examined joint patents with local firms/total	Examined joint patents with local SMEs/joint patents (**H2b**)	Firms' solo application of joint patents	
LPTC	0.764	0.768	0.753	0.468	
University	0.760	0.771	0.725	0.447	

Panel C	Examiner forward citations per patent*	Examiner forward citations per joint patent*	PCT application/total**	The number of claims per patent**	
LPTC	1.517	2.244	0.028	6.375	
University	1.318	1.825	0.083	7.929	

Notes

1. The unit of analysis is a prefecture. N=47.
2. The statistical level of significance for t-test. ** $p<0.01$; * $p<0.05$.

Table 2 LPTC patents by type

Panel A**	1	2	3	4	5	6			
Manufacturing	0.187	0.278	0.230	0.124	0.137	0.044			
Agriculture	0.351	0.115	0.393	0.022	0.098	0.022			
Environment & public health	0.500	0.236	0.038	0.009	0.142	0.075			
Medicine	0.603	0.050	0.030	0.050	0.261	0.005			
Panel B	Cosine similarity to local SMEs**	Joint patents with local SMEs/ joint patents†	Examined joint patents with SMEs / joint patents**	Examiner forward citations per patent**	PCT application/ total**	The number of claims per patent**			
Manufacturing	0.599	0.204	0.424	1.549	0.015	6.182			
Agriculture	0.544	0.131	0.162	1.250	0.004	5.733			
Environment & public health	0.362	0.138	0.167	1.594	0.029	7.221			
Medicine	0.300	0.035	0.267	3.670	0.124	9.959			
Panel C	Testing**	Open labs**	Consultation**	Seminars	Funded	Joint	Royalties	Papers	Ph.D.**
Manufacturing	143.525	59.787	89.188	1.571	873.221	0.138	8.198	0.201	0.206
Agriculture	2.577	5.045	24.526	1.611	122.817	0.059	1.006	0.390	0.098
Environment & public health	149.542	0.842	1.776	0.343	204.652	0.064	1.291	0.295	0.234
Medicine	14.355	52.735	67.946	1.297	239.936	0.063	0.000	0.151	0.377

Notes

1. The unit of analysis is an LPTC. N=293.
2. The statistical level of significance for the chi square test (Panel A) and ANOVA (Panel B and Panel C). ** $p<0.01$; * $p<0.05$; † $p<0.1$.
3. Technological fields: 1. Biotechnology; 2. Chemistry excluding biotechnology; 3. Mechanical engineering; 4. Electrical engineering; 5. Instruments; 6. Others.
4. For Panel C, all variables are divided by the number of LPTC researchers.

Table 3 The Spearman rank-order correlation coefficients between LPTCs' technology transfer channels and location quotients of SMEs in the region

	1	2	3	4	5	6
Testing	-0.247†	0.114	0.169†	-0.110	0.014	0.030
Open labs	-0.056	0.010	0.021	-0.007	0.031	-0.100
Technical consultation	-0.236†	-0.047	0.159†	-0.126	0.015	-0.022
Seminars	0.000	0.034	0.124	-0.021	0.002	-0.139†
Funded research	0.024	-0.073	-0.129	0.149†	0.017	0.060
Joint research	0.226†	0.185†	-0.060	0.030	-0.043	-0.128
Royalties	0.161†	0.044	-0.157†	-0.106	-0.137†	0.113
Papers	0.034	-0.033	-0.046	0.011	0.002	0.116
Ph.D.	-0.046	-0.063	-0.033	-0.112	-0.087	0.326†

Notes

1. The unit of analysis is an LPTC. N=293.
2. Technological fields: 1. Biotechnology; 2. Chemistry excluding biotechnology; 3. Mechanical engineering; 4. Electrical engineering; 5. Instruments; 6. Others.
3. † denotes the 10% level of statistical significance.
4. See Appendix Table 2 for definitions of variables.
5. All variables are divided by the number of LPTC researchers.

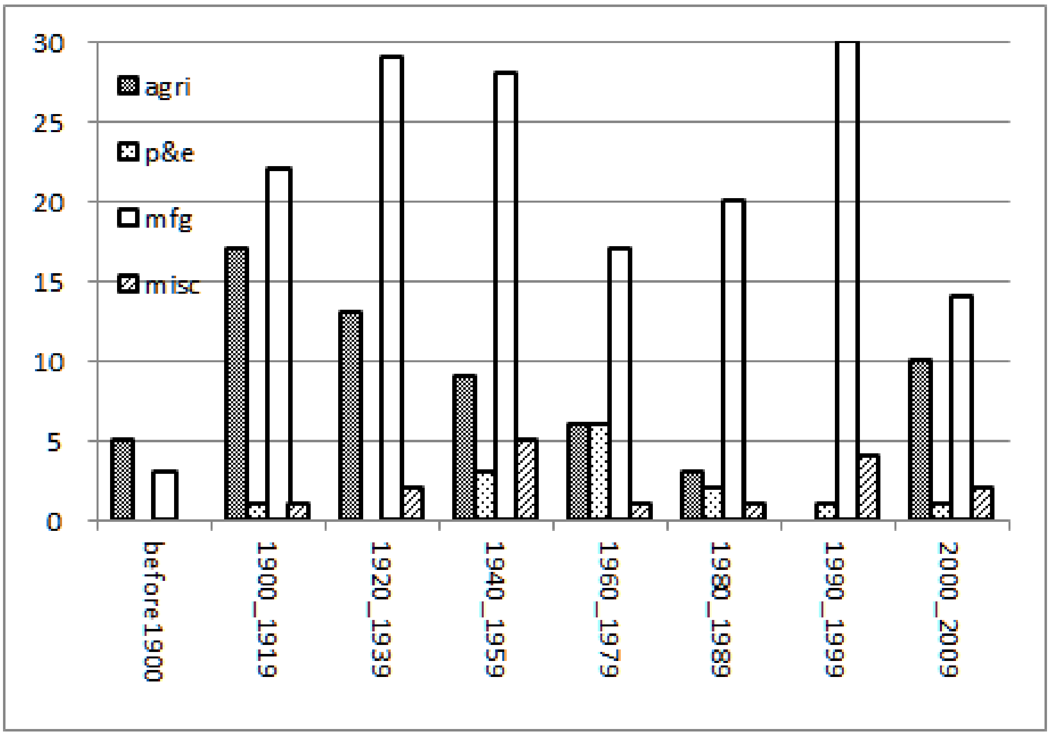
Table 4 The Spearman rank-order correlation coefficients among technology transfer channels

	Testing	Open labs	Consult	Seminars	Funded	Joint	Royalties	Papers	Ph.D.
Testing	1.000								
Open labs	0.552*	1.000							
Consultation	0.530*	0.636*	1.000						
Seminars	-0.009	0.131	0.320*	1.000					
Funded	-0.073	0.087	0.074	-0.097	1.000				
Joint	0.162	0.152	0.035	0.055	-0.096	1.000			
Royalties	0.180*	0.262*	0.285*	0.107	0.317*	0.022	1.000		
Papers	-0.192*	-0.234*	-0.159*	-0.007	0.180*	-0.177	0.013	1.000	
Ph.D.	0.156*	0.150*	0.101	-0.080	0.431*	-0.183*	0.333*	0.494*	1.000

Notes

1. The unit of analysis is an LPTC. N=293.
2. * denotes the 5% level of statistical significance.
3. See Appendix Table 2 for definitions of variables.
4. All variables are divided by the number of LPTC researchers.

Appendix Figure 1 Distribution of establishment year of LPTCs



Source: AIST "Current Status of Local Public Technology Centers"

Note

agri: agriculture; p&e: environment and public health; mfg: manufacturing; misc: not elsewhere classified

Appendix Table 1 Technological fields based on IPC8 Technology Concordance

Fields	Examples
1. Biotechnology	Biotechnology, environment technology, food chemistry, pharmaceuticals
2. Chemistry excluding biotechnology	Basic materials chemistry, chemical engineering, macromolecular chemistry, polymers, materials, metallurgy, microstructural and nanotechnology, organic fine chemistry, surface technology, coating
3. Mechanical engineering	Engines, pumps, turbines, handling, machine tools, mechanical elements, other special machines, textile and paper machines, thermal processes and apparatus, transport
4. Electrical engineering	Audio-visual technology, basic communication processes, computer technology, electrical machinery, apparatus, energy, IT methods for management, semiconductors, telecommunications
5. Instruments	Analysis of biological materials, control, measurement, medical technology, optics
6. Others	Civil engineering, furniture, games, other consumer goods

Appendix Table 2 Definitions of variables and descriptive statistics

	Definition	N	Mean	S.D.	Min	Max
Testing	The times testing conducted	145	106.23	144.2	0.000	947.2
Open labs	The times labs used	151	42.54	75.8	0.000	515.4
Consultation	The times technical consultation conducted	151	67.67	69.0	0.000	482.0
Seminars	The times seminars for technology diffusion held	148	1.65	3.2	0.003	28.5
Funded	Revenue from funded research	148	645.32	5474.8	0.000	66659
Joint	The number of joint research projects	86	0.13	0.1	0.013	0.5
Royalties	Revenue from licensing	146	5.96	17.0	0.000	114.7
Papers	The number of scientific publications	145	0.26	0.4	0.000	4.0
Ph.D.	The number of Ph.D. researchers	144	0.18	0.1	0.000	0.8

Note

All variables are divided by the number of LPTC researchers.