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Assessing technology transfer 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) are technology transfer organizations administrated by the local authorities and aim to help local SMEs (small- and medium-sized enterprises) improve productivity. This study evaluates technology transfer activities of LPTCs from the viewpoints of regional and sectoral innovation systems. Specifically, this study examines three research questions. First, this study examines different roles LPTCs and universities play in regional innovation systems. Second, this study examines how LPTCs develop technology transfer channels in accordance with characteristics of sectoral innovation systems. Third, this study investigates whether joint patents of LPTCs act as a conduit of regional knowledge spillover. Quantitative analysis of patent data reveals the following. First, LPTCs possess technological knowledge that fit better with regional innovation systems than do universities. Second, in regions where SMEs specialize in chemical innovations, LPTCs engage in licensing more intensively, which aligns with theoretical predictions from sectoral innovation systems. Third, LPTCs collaborate with local firms than do universities while there is no significant difference between LPTCs and universities in the probability of joint patents? being examined and self-cited by collaborators.

Jelcodes:O38,R11

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Keywords

Technology transfer, SMEs, regional innovation systems, sectoral innovation systems, innovation intermediary

JEL

O33, O34, R11, R12

1. Introduction

Local public technology centers (LPTCs) are technology transfer organization, administrated by the prefectural and municipal government. LPTCs were first established to improve productivity in agriculture in the late 19th century and had been augmented in terms of both geographical and technological coverage throughout the 20th century. Now, LPTCs engage in technological support for small- and medium-sized enterprises (SMEs) in all prefectures and in most of the technological fields. Technological support LPTCs offer SMEs include the inspection of raw materials and final products, technical guidance and consultation, workshops for the diffusion of new technologies, and usage of experiment facilities SMEs cannot afford. Furthermore, LPTCs conduct their own research and license out their patented technologies mainly to local SMEs.

Since 2000s, LPTCs have been faced with two structural changes that had them redefine their roles in and contributions to regional innovation systems. First, the prolonged economic stagnation since the 1990s has left the local authorities with serious financial difficulties. Furthermore, as a result of the government's structural reform in the 2000s, the local authorities had their subsidies reduced substantially. Consequently, the local authorities reduced the budgets of LPTCs and started to rigorously evaluate their performance and contributions to the regional economy. Second, the national innovation system was fundamentally reformed since the late 1990s, which was symbolized by the incorporation of national universities in 2004. A series of reforms required national universities in a region to share knowledge with small local firms, whereas before the reforms, they had not been motivated to be involved in the regional economy. This change marked the national universities' entry into the local market for public technological services which was initially dominated by LPTCs.

Under these circumstances, LPTCs are required to establish their own strategy to function as part of a regional innovation system. Using comprehensive databases on patents and LPTCs, this study aims to quantitatively evaluate the roles played by LPTCs in regional and sectoral innovation systems. technological knowledge held by LPTCs, technology transfer channels offered by them, and regional knowledge spillover through joint patents between LPTCs and local firms. Although much research has been conducted on university spillovers in Japan (Motohashi, 2005; Kneller, 2007), local public technology centers as a source of public knowledge have received little attention from researchers. Therefore, this analysis should intrigue the researchers interested in technology transfer and regional development, as well as policymakers responsible for developing strategies for local public technology centers.

This study evaluates LPTCs by exploring three research questions. First, this study examines different roles LPTCs and universities play in regional innovation systems. LPTCs are expected to help local SMEs innovate and improve productivity. Therefore, technological resources LPTCs possess are predicted to better fit with characteristics of small firm innovation in the region than do universities. Second, this study examines how LPTCs develop technology transfer channels in accordance with characteristics of sectoral innovation systems. The concept of a sectoral innovation system highlights sectoral variations in the creation and diffusion of new knowledge. According to this framework, in regions where SMEs more actively innovate in drugs and chemicals, LPTCs would engage more intensively in licensing because patents are very effective as a means of appropriation and dissemination of analytical knowledge. On the contrary, in regions where SMEs innovate more actively in mechanical engineering and electronics, LPTCs would conduct more technical guidance and consultation because face-to-face communications are required for the efficient transfer of synthetic knowledge. Third, this study investigates whether joint patents of LPTCs act as a conduit of regional knowledge spillover. This study captures research networks of LPTCs as joint inventions with firms and examines how research networks of LPTCs are localized and the type of recipients of knowledge spillover. Furthermore, this study evaluates how joint patents of LPTCs are developed by the firms by using the data of patent citations and examination.

2. Theoretical backgrounds

Previous studies provide two significant frameworks in evaluating how new knowledge is created and disseminated. One is the concept of regional innovation systems that originally comes from the idea of national innovation systems that highlights interactions, rather than independent efforts, among industry, universities, public research institutes, and government in the creation and dissemination of knowledge (Nelson et al. 1993). According to the framework of national innovation systems, fostering spillover from public knowledge, such as university research, is the key to promote industrial innovations as well as to strengthen research capability of the private sector. As for regional innovation systems, localized flow of knowledge is the key concept. Knowledge spillover could be constrained by geographical distances as some technologies in the embryonic stage consist of tacit knowledge that requires face-to-face communications for the efficient transfer, which prefers geographical proximity. This implies that a region will be a key unit of analysis in the promotion of industrial innovations.

In regional innovation systems, LPTCs are considered innovation intermediaries that directly and indirectly promote innovations through technological support for SMEs and helping local firms establish knowledge networks (Howells 2006). Technology transfer activities of LPTCs are embedded in the region since most of the users of technological services of LPTCs are local SMEs. On the contrary, universities are engaged in basic research and likely to develop global research networks rather than regional linkages to small local firms. Therefore, LPTCs are predicted to show greater similarity to characteristics of regional innovation systems in terms of technological resources they retain, compared to those universities possess. Based on these discussions, two hypotheses are derived about the different roles played by LPTCs and universities in a regional innovation system.

H1a: The similarity of technological knowledge between LPTCs and SMEs is greater than that of universities and SMEs.

H1b: The similarity of technological knowledge between LPTCs and large firms is smaller than that of universities and large firms.

Another theoretical framework to analyze the creation and diffusion of new knowledge is the concept of a sectoral innovation system that argues that innovations in different sectors build on different types of knowledge that require different modes of transfer (Pavitt 1984; Malerba 2002; Asheim et al. 2007). Innovations in biotechnology and information communication technology tend to build on analytical knowledge that can be defined as knowledge to understand and explain features of the universe. Knowledge inputs and outputs of this type tend to get codified. Reviews of scientific articles and the application of scientific principles are critical inputs for innovations of this type. Knowledge outputs are likely to be embodied into patent documents and transferred via licensing without geographical constraints. On the contrary, innovations in mechanical engineering tend to build on synthetic knowledge that can be defined as knowledge to design something that work as a solution to a practical problem. Knowledge is created through heuristic approach rather than deductive process, which makes know how and tacit knowledge more important for innovations of this type. As the efficient transfer of tacit knowledge requires face-to-face communications among scientists and engineers, innovations of this type tend to be disseminated through technical consultation which prefers geographical proximity. Therefore, types of innovations dominant in a region would affect channels of technology transfer LPTCs should arrange. Considering most of the users of LPTCs' technology transfer activities 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.

H2a: In regions where SMEs' innovative activities concentrate more in chemicals and drugs, LPTCs engage in licensing more intensively.

H2b: In regions where SMEs' innovative activities concentrate more in mechanical engineering, LPTCs engage in technical consultation more actively.

As a technology transfer organization administrated by local authorizes, LPTCs are supposed to make greater commitment to regional development than do universities in the region. It is common for LPTCs to conduct joint research with a user firm, most of which are local SMEs, that asked LPTCs technical consultation in the first place, which leads to joint invention and joint application of patent. Therefore, it is predicted that joint patents of LPTCs tend to include more local and small-sized collaborators than do those of universities.

H3a: LPTC joint patents tend to have more local collaborators than do university joint patents.

H3b: LPTC joint patents tend to have smaller collaborators than do university joint patents.

From a legal perspective, university-industry joint research has been considered 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 other co-owners (in this case the industry partner). This legal environment could offer large firms a great advantage to preempt the outcomes of university research through joint research. Given the legal environment, the industry partner may not intend to use a joint invention internally, and may exploit joint research for a strategic purpose, such as to block competitors. Considering that significant part of academic knowledge stock has been created by national universities in Japan, preemption could deteriorate social welfare in terms of the efficient diffusion of outcomes from publicly funded research.

These arguments suggest the absence of knowledge spillovers in university-industry collaborations, rather than the acquisition of complementary knowledge from academic research. As for technology transfer activities of LPTCs, research collaborators of LPTCs are local SMEs. Empirical findings about variations in patent strategies by firm size reveal that strategic use of patents, such as preempt related technologies to prevent competitors from patenting them, is typically seen for large firms while SMEs tend to use patents for internal use (Giuri et al. 2005; Nagaoka and Walsh 2009). Therefore, university joint patents could be used as a means of preemption by large firms while collaborators of LPTCs are keen to commercialize joint inventions and have little incentives to use joint patents to block competitors. Assuming that collaborators' ongoing interest in further development of joint inventions could be measured as the probability of joint patents' being examined by the patent office and self-cited by the collaborator, two hypotheses could be derived from these arguments.

H3c: LPTC joint patents tend to be examined more than do university joint patents.

H3d: LPTC joint patents tend to be self-cited by the partner firm more than do university joint patents.

3. Method

This study uses the Institute of Intellectual Property Patent Database (IIPPD), which is a comprehensive database of the patents applied for the Japan Patent Office (JPO), to create a dataset used for the evaluation of LPTCs. The version used in the analysis was released in May 2014. In order to identify applicants' firm size, this study employs the National Institute of Science and Technology Policy (NISTEP) Corporate Database (NCD) which was released in November 2014. The SME Basic Law's definition was employed to classify micro businesses (firms with less than 21 employees in manufacturing), SMEs (firms with less than 301 employees in manufacturing), and large firms. Micro businesses are integrated into SMEs. NCD collects information about firms that are listed or have more than 999 patents. Therefore, only R&D-intensive SMEs are identifiable from NCD. The dataset contains 3,793,893 patents of which 4.7% were filed by SMEs and 66.6% were filed by large firms, which means that 28.6% of the applicants (e.g., unlisted large firms and R&D-inactive SMEs) were not identifiable using NCD.

The dataset is compiled by region, technology, and time. The geographical unit of analysis is a prefecture which is a local unit of governance in Japan. There are 47 prefectures. An average prefectures 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). It has been known that it is appropriate to identify the location of innovation at the level of inventors, instead of applicants. This is particularly true of innovative activities of large firms. If the location of innovation is identified at the level of applicant address, innovations of large firms would extremely concentrate in Tokyo and Osaka where headquarters of most large firms are located. As for university patents, patents invented by national universities (before the incorporation of national universities in 2004) were filed by a nation or an individual. This makes it difficult to identify the location of innovation from applicant address because of the unavailability of information about home addresses of university inventors. As for LPTC patents, most of the LPTCs do not possess a legal entity, which makes local authorities apply for patents invented by LPTCs. It is, however, not possible to assume that all the patents filed by local authorizes are created by LPTCs because local authorities have other divisions, such as public universities, that may create patentable technologies. Therefore, this study employs inventors address to identify patents created by LPTCs. As for technological fields, this study employs six classifications introduced by NBER which are chemicals excluding drugs, computers and communication, drugs and medical devices, electronics, mechanical engineering, and others (see Appendix Table 1.). As for empirical period, this study uses information of patents applied for JPO between 2000 and 2009.

To tackle with the first research question, this study compares the similarity of technological knowledge held by LPTCs and universities to regional innovation systems measured as innovations by SMEs and their larger counterparts. The actual process to identify the location of innovation for each constituency of a regional innovation system can be summarized follows. (1) Large firms tend to have a policy that requires inventors to indicate the headquarter of the firm as inventor address, instead of home address of inventors or research laboratory of the firm. Therefore, for firms with such policy, this study assumes that the headquarter and research laboratory of the firm are located in the same prefecture. For firms without such policy, this study assumes that home of an inventor and a 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 inventor address that includes the name of the firm. (2) SMEs normally do not to have such policy about how inventors indicate their addresses in patent documents. Even though SMEs require inventors to indicate the headquarter, it is unlikely for SMEs to have a headquarter and a research laboratory in different prefectures. Furthermore, it is unlikely for SMEs' employees to commute beyond a border of prefectures. Therefore, this study identifies the location of SMEs' invention as a prefecture indicated in inventor address that includes the name of the firm. (3) University inventors could indicate either home or university in inventor address. It is not possible, however, to collect information of all university inventors' home addresses. Therefore, this study assumes that, if university inventors indicate their home in inventor address, their home and university laboratory are located in the same prefecture, which means that there is no commuting beyond prefectures. Based on these assumptions, this study identifies the location of invention as a prefecture indicated in inventor address that includes the name of the university with which the inventor is affiliated. (4) LPTC inventors could also indicate either their home or an LPTC in inventor address. For the same reason as SMEs' inventions, this study identifies the location of invention as a prefecture indicated in inventor address that includes the name of the LPTC.

The similarity of technological knowledge held by LPTCs and universities to regional innovation systems is measured using cosign similarity index (*cossim*) which can be defined as $cossim(X, Y)=\{X ,Y\}/|X|*|Y|$. A vector X_{ij} denotes SMEs' patents in a prefecture i and a technological field j while another vector Y_{ij} denotes LPTCs' patents (or local university's patents) in i and j (j=1…6). Cosign index was calculated by prefecture. This index captures how the portfolio of technological resources possessed by large firms, SMEs, universities, and LPTCs is similar to another. For instance, if most of the local universities specialize in life sciences while most of the local SMEs are engaged in the machinery industry, the similarity of universities to SMEs of the prefecture will be small.

To address the second research question, correlation coefficients between LPTCs' technology transfer channels and specialization index of local SMEs' innovative activities. Specialization index is measured by location quotient, $LQ=(X/Y)/(X'/Y')$. X is patents in a specific field, in a prefecture, and Y is all patents in the prefecture. X' and Y' are patents in that field, in Japan and all patents in Japan, respectively. LQ was calculated by technological field. The more specialized innovative activities are in a specific technological field, the greater location quotient of that technological field will be. For instance, if local SMEs concentrate in drug discovery more than population mean, location quotient of the prefecture will be the highest in drugs (i.e., 3 in NBER classification).

In order to operationalize 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 Ph.D., testing, open laboratory, workshops for the diffusion of new technologies, technical consultation, guidance, joint research, patents that were licensed, and scientific articles. 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. Average from 2000 to 2009 was used for analysis. Summary statistics are in Appendix Table 2.

To address the third research question, this study operationalizes the localization of knowledge networks of LPTCs and universities using a patent database as follows. Research collaborations of LPTCs and universities with firms could yield joint inventions that could be filed as joint patents. Or, outcomes of joint research could be transferred voluntarily to the private sector in return for donation, which used to be common for collaborations between universities and large firms. Joint inventions are defined as patents that have multiple inventors. Joint patents are defined as patents that have multiple 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 a joint invention but a solo patent. Joint inventions represent research networks of LPTCs and universities. This study captures the characteristics of research networks as localization and the type of recipients. The proportion of local collaborators to joint inventions measures the localization of research networks. The proportion of SMEs to joint inventions measures the type of recipient of knowledge spillover. Some joint patents could be left unexamined because firms are uninterested in commercialization but do not want other firms patent the idea. Thus, it is considered that the proportion of unexamined patents to joint patents represents firms ongoing interest in further development of joint invention. Similarly, if the collaborator is interested in commercialization of joint invention, it is likely that the firm self cites the joint patent. Thus, the probability of joint patents' being self cited represents the collaborator's ongoing effort to commercialize the joint invention.

4. Results

As for the first research question, Figure 1 shows that the number of prefectures where LPTCs show greater similarity than universities is 33 while the number of prefectures where universities show greater similarity than LPTCs is 14. Cosign similarity between LPTCs and SMEs is .75 while cosign similarity between universities and SMEs is .66. Therefore, H1a is supported. Figure 2 shows that the number of prefectures where LPTCs show greater similarity than universities is 18 while the number of prefectures where universities show greater similarity than LPTCs is 29. Cosign similarity between LPTCs and large firms is .70 while cosign similarity between universities and large firms is .74. Therefore, H1b is supported. The results show that technological knowledge LPTCs possess is complementary to innovation activities of local SMEs, which is consonant with findings of previous literature.

Figures 1 and 2 here

As for the second research question, Table 1 shows that, in regions where innovative activities of SMEs concentrate in the field of chemicals, LPTCs tend to do more licensing measured as greater amount of royalty revenue. This is consonant with the notion of sectoral innovation systems that the transfer of analytical knowledge prefers patent licensing. Therefore, H2a is supported. In regions where innovative activities of SMEs concentrate in mechanical engineering, LPTCs are predicted to engage in technical consultation more intensively that contains great extent of face-to-face communications which are required for the transfer of tacit knowledge. However, it is difficult to observe a systematic relationship between technology transfer channels and characteristics of sectoral innovation systems. Therefore, H2b is not supported.

Table 2 shows that testing and open labs are closely associated with technical consultation and guidance. Furthermore, open labs are significantly correlated with more interactive technology transfer channels like joint research but testing is not. This may stem from the fact that letting SMEs use LPTCs' equipments could encompass training of engineers. Such interactions through employee training may provide SMEs with a basis to initiate joint research with LPTCs. Joint research, however, does not necessarily guarantee the successful commercialization of joint inventions measured as the amount of royalty LPTCs gain. Revenues from funded research and licensing are greater when LPTC researcher exhibit higher scientific quality in terms of educational backgrounds and scientific outputs. This suggests that localized technology transfer channels, such as technical consultation, foster understanding about technological needs of local firms whereas to strengthen scientific basis of LPTC researchers improves technology transfer productivity in terms of quality.

Tables 1 and 2 here

As for the third research question, Table 3 shows that there is little difference in the probability of collaboration with firms between LPTCs and universities. Localized collaboration is common for LPTCs, but not for universities. Therefore, H3a is supported. The probability of collaboration with local SMEs is low, which might have stemmed from the fact that non R&D-performing SMEs that are key users of LPTCs were not identifiable from NCD. Therefore, H3b is not supported. Table 3 also shows that university patents are far more likely to be filed solely by firms than are LPTC patents, which suggests the voluntary transfer of academic inventions to large firms that have informal connections to scientists as a key route of university-industry collaborations. The probability of joint patents' being unexamined does not differ between LPTCs and universities. Therefore, H3c is not supported. The probability of joint patents' being self-cited by the collaborator, the firm jointly invented the technology, is higher when firms collaborate with universities than do with LPTCs. This suggests the absence of preemption through collaborations between universities and large firms. Therefore, H3d is not supported.

Table 3 here

5. Discussion

The results provide policy implications regarding how LPTCs should be developed in response to changes in industrial structure and financial status of local authorities. Specifically, the results suggest three directions of LPTCs according to their technological specialization and key technology transfer channels.

Type A: LPTCs encompass various technologies, seeking for scope economies

Most of the LPTCs in manufacturing fall into this type. They are expected to respond to technological needs in various industries, which makes the similarity of LPTCs of this type to regional innovation systems lower than dedicated LPTCs. It is considered that scope economies improve technology transfer productivity when systemic innovations are dominant in regional innovation systems. Systemic innovations can be defined as innovations that require knowledge inputs from various fields of technologies. A typical example of systemic innovation is semiconductor where knowledge inputs from solid-state physics, metallurgy, and electrical engineering are indispensable. This implies that LPTCs with more diversified knowledge backgrounds, such as medicine, biology, agriculture, biotechnology, and environment, would have more serendipitous discoveries in research. Therefore, in regions where SME innovations are characterized as systemic innovations, LPTCs with broader sources of knowledge are likely to develop technology transfer to SMEs more efficiently. LPTCs of this type have been tackling with reorganization since 2000s when local authorities encountered serious financial difficulties. Some LPTCs of this type became incorporated after 2006, seeking for scope economies through organizational integration and autonomy in terms of budget allocation and human resource management. As there is no empirical evidence so far regarding how scope economies of LPTCs affect technology transfer productivity according to sectoral innovation systems, future study should analyze the changes in technology transfer productivity of LPTCs after incorporation.

Type B: LPTCs devoted in a specific technology, exploiting division of labor
Some LPTCs devote to specific technology according to the type and size of demand for public technological service that reflects natural, industrial, and historical backgrounds of the region. They include LPTCs in ceramics, textiles, paper, leather, brewery, agriculture, fishery, forestry, and livestock. According to knowledge base and technology transfer channels, they could be reorganized as Type A. LPTCs of this type should be abolished in the case of dramatic decrease in demand for technology transfer by the public sector.

Type C: LPTCs devoted in a specific technology, exerting scale economies
The geographical coverage of LPTCs' technology transfer activities is bound by the transfer channel that is the most localized. As the geographical range of provision of technical guidance and consultation is limited, technology transfer activities would have to be locally embedded. On the contrary, licensing activities are less geographically constrained. This implies that LPTCs can make technology transfer more efficient by expanding activities beyond prefectural borders, thereby generating scale economies through retaining access to various potential licensees and spreading administrative cost (Lach and Schankerman 2008). The results show that this type of development would be relevant for LPTCs specialized in chemistry that exhibit greater inclination to licensing. The results suggest that technical consultation increases the number of patents licensed, which suggests that understanding about local needs improves technology transfer productivity. However, the results also show that the successful commercialization of LPTC inventions through licensing requires firm academic basis of LPTC researchers. This suggests that the improvement of human resources, such as collaborations with universities to have researchers get a Ph.D., would help LPTCs adopt this approach.

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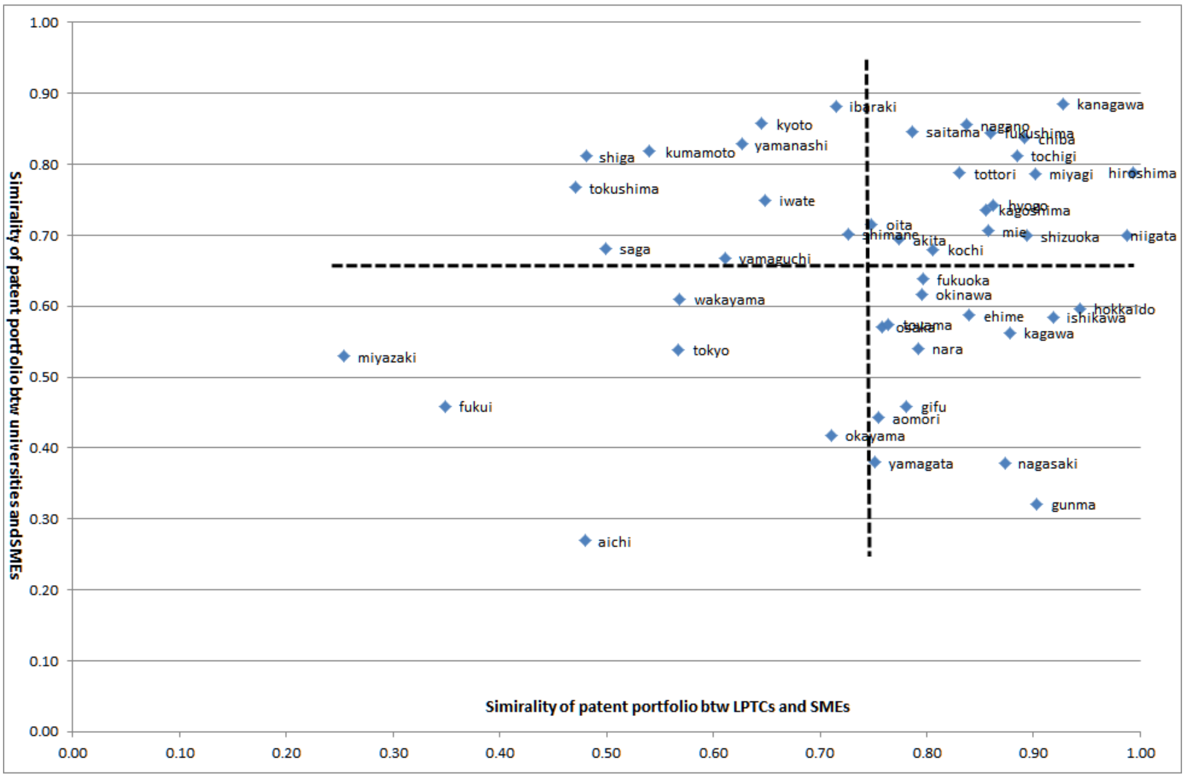
Figure 1 Similarity between LPTCs, universities, and SMEs

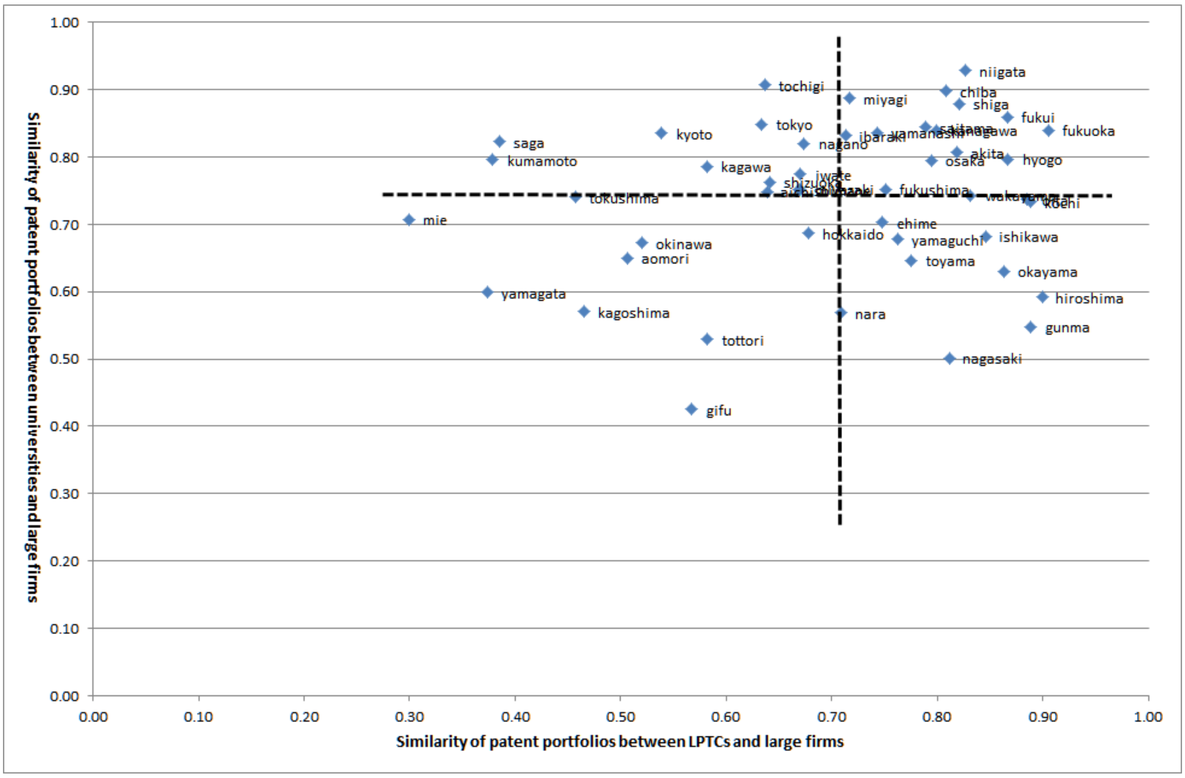


Notes

Each diamond denotes a prefecture.

Each dotted line represents average.

Figure 2 Similarity between LPTCs, universities, and large firms



Notes
Each diamond denotes a prefecture.
Each dotted line represents average.

Table 1 Pair-wise correlation between LPTCs' technology transfer channels and location quotients of SMEs

NBER	1	2	3	4	5	6
Testing	0.000	-0.105	-0.118	0.030	**-0.208**	**0.230**
Open lab	-0.060	0.015	-0.082	0.088	0.168	-0.087
Consultation	-0.088	0.030	-0.155	0.013	-0.050	0.139
Technical guidance	-0.139	0.067	-0.009	0.139	-0.091	0.008
Workshop	0.020	-0.027	-0.072	0.038	0.068	-0.018
Funded research revenue	-0.019	-0.023	0.026	-0.024	-0.072	0.073
Joint research	0.145	-0.174	0.134	**0.390**	-0.078	**-0.327**
Licensed-out patents	0.170	-0.122	0.041	-0.065	0.011	-0.005
Royalty	**0.235**	0.109	-0.116	0.052	-0.053	-0.135
Publication	-0.107	-0.113	-0.066	0.136	-0.010	0.076
Ph.D.	0.017	**-0.223**	-0.040	**-0.181**	**0.251**	0.118

Note
Highlighted by bold denotes the level of statistical significance < .1.

Table 2 Correlation coefficients among technology transfer channels

	Testing	Open	Consult	Guide	Workshop	Funded	Joint	lpatent	Royalty	Paper	Phd
Testing	1.000										
Open lab	0.078	1.000									
Consultation	**0.390**	**0.401**	1.000								
Guidance	**0.197**	**0.243**	**0.310**	1.000							
Workshop	-0.013	**0.284**	0.126	-0.029	1.000						
Funded research	-0.171	-0.070	0.005	-0.075	-0.175	1.000					
joint research	0.140	**0.512**	0.192	0.042	**0.343**	-0.170	1.000				
Licensed-out patents	0.024	-0.048	**0.234**	0.047	-0.009	-0.057	-0.034	1.000			
Royalty	-0.100	**0.253**	0.037	-0.132	**0.265**	0.110	-0.072	**0.568**	1.000		
Publication	-0.117	-0.122	-0.050	-0.075	**0.238**	**0.338**	**-0.267**	0.154	**0.361**	1.000	
Ph.D.	0.103	0.049	0.107	-0.054	-0.051	**0.346**	-0.208	**0.408**	**0.297**	**0.178**	1.000

Note

Highlighted by bold denotes the level of statistical significance <.1.

Table 3 Joint inventions between LPTCs, universities, and firms

	Ratio of joint invention with firms (A) A/total	Ratio of joint invention with local firms (B) B/A	Ratio of joint invention with local SMEs (C) C/B	Ratio of joint invention filed solely by firms (D) D/A	Ratio of intl. joint patents
Joint invention between LPTCs and firms	0.51	0.68	0.03	0.17	0.00
Joint invention between universities and firms	0.47	0.30	0.05	0.44	0.01

	Ratio of unexamined patents (E) E/A	Ratio of unexamined joint patents (F) F/A	Ratio of unexamined joint patents with local firms (G) G/B	Ratio of self cited joint patents with firms (H) H/A	Ratio of self cited joint patents with local firms (I) I/B
Joint invention between LPTCs and firms	0.25	0.24	0.25	0.09	0.07
Joint invention between universities and firms	0.26	0.23	0.22	0.16	0.13

Appendix Table 1 Technological classification

ITC	NBER	Field	IPC
1	6	Agriculture	A01(excluding A01N)
2	6	Foods	A21-A24
3	6	Household products	A41-A47
4	3	Medical devices, entertainment(A63F)	A61(excluding A61K)-A63(A63F is classified in 6)
5	3	Drugs	A61K
6	1	Processing	B01-B09
7	5	Metal processing, machine tools	B21-B23
8	5	Cutting, material processing	B24-B32(excluding B31)
9	6	Printing	B41-B44
10	5	Vehicles, ships, airplanes	B60-B64
11	5	Wrapping	B65-B68
12	1	Inorganic chemical	C01-C05
13	1	Organic chemical	C07,A01N
14	1	Polymer molecule	C08
15	1	Detergent	C09-C11
16	3	Beer, alcohol	C12-C14
17	3	Genetic engineering	C12N15/
18	5	Metallurgy	C21-C30
19	6	Textiles	D01-D07
20	6	Pulp, paper	D21,B31
21	6	Construction	E01-E06
22	6	Mining	E21
23	5	Engineering	F01-F04,F15
24	5	Machinery	F16-F17
25	6	Lighting	F21-F28
26	6	Weapons	F41-F42,C06
27	4	Measurement, optical	G01-G03
28	2	Computers	G04-G08
29	2	Display devices, information storage	G09-G12
30	4	Nuclear engineering	G21
31	4	Semiconductor	H01-H02,H05
32	2	Electric circuits	H03-H04
33	6	Others	B81,B82

Appendix Table 2 Definitions of variables

	Definition (all variables are divided by the number of LPTC researchers)	N	Mean	Std.dev.	Min	Max
Testing	The number of times testing and inspection were conducted	87	108.6	125.3	0	514.1
Open lab	The number of times open laboratories were used	92	47.8	85.2	0	515.4
Consultation	The number of times technical consultation was offered	92	74.6	66.2	0	323.0
Guidance	The number of times technical guidance was offered	82	21.4	34.8	0	160.4
Workshop	The number of times workshops for the diffusion of new technologies were held	89	1.3	1.2	0	7.4
Funded research	Revenue from funded research	78	1261.0	7518.4	0	66659
joint research	The number of joint research projects	49	0.11	0.10	0.01	0.48
Licensed-out patents	The number of patents that were licensed	85	0.14	0.24	0	1.86
Royalty	Revenue from license	67	25.2	46.1	0	218.3
Publication	The number of academic articles	88	0.26	0.48	0	4.03
Ph.D.	The number of Ph.D. scientists	88	0.21	0.14	0	0.76