Strategic Fit Between Regional Innovation Policy and Regional Innovation Systems: The Case of Local Public Technology Centers in Japan

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Abstract Local public technology centers are publicly-managed technology transfer organizations, and their resource allocation strategies represent policy instruments for the promotion of localized knowledge spillovers. Since substantial regional differences exist with regard to the need for public technological services, policy instruments should consider these differences. This study develops a model and a method to evaluate whether the regional innovation policy matches the characteristics of a regional innovation system. The results indicate that the resource allocation strategies of technology centers have not been developed according to the needs of the regional environment; hence, technology transfer activities may not have been optimally utilized to facilitate regional economic development.

1 Introduction

A regional innovation system is a conceptual framework in which industrial innovations are generated through interactions among the industries, universities, and government of a region (Howells 1999; Cooke et al. 2004; Mowery and Sampat 2005). The regional perspective is important when the geographical range of knowledge diffusion among economic agents is limited because of the tacit nature of the knowledge transferred. Since university knowledge is disseminated through publication, it does not encounter geographical limitations in diffusion. However, a number of empirical studies have indicated that spillovers from university research tend to be localized (Jaffe 1989; Anselin et al. 1997; Autant-Bernard 2001). That is, one economic agent near the university may benefit from university spillover,

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whereas another in a geographically isolated area will not benefit from the spillover. Therefore, policy instruments for the promotion of the exchange of knowledge among industries, universities, and public research institutions can improve knowledge productivity in the region (Fritsch 2004; Fritsch and Franke 2004; Ronde and Hussler 2005). In the long run, regional differences in knowledge productivity will lead to regional differences in economic development.

Among the regional innovation policies that have been implemented in developed countries, the establishment and expansion of local public technology centers in Japan constitute one of the most distinguished policy instruments. Local public technology centers, administrated by the prefectural and municipal governments, engage in providing technological support to small local firms. The centers were established before modern economic growth began in the nineteenth century; they increased in number during the twentieth century; and they now cover all prefectures and most technological categories. The technological services the centers offer to small local firms include the inspection of materials and products, technological consultation, diffusion of new technologies, joint research, and funded research. Furthermore, local public technology centers conduct their own research and license out their patented technologies mainly to small local firms. The US government was of the opinion that local public technology centers significantly contributed to economic development in postwar Japan, and this policy instrument was benchmarked in the design of the regional innovation policy implemented in the 1990s in the US (U.S. Congress 1990; Shapira et al. 1995, 1996; Feller et al. 1996).

As noted above, local public technology centers are remarkable in terms of their history, geographical and industrial coverage, variety of services offered, and number of policy recipients. However, local public technology centers currently face two structural changes that could force them to redefine their capabilities and responsibilities in the regional innovation system. 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 the local public technology centers (see Fig. 1) and rigorously evaluated their performance. In order to budget more efficiently, the local authorities required local public technology centers to redefine their strengths and contributions to the regional economy more explicitly. Second, the national system of innovation was fundamentally reformed during and after the 1990s; this was symbolized by the enactment of the Science and Technology Basic Law in 1995, the Technology Licensing Organization Act in 1998, the Law of Special Measures for Industrial Revitalization in 1999, the Law to Strengthen Industrial Technology in 2000, and the incorporation of national universities in 2004. A series of reforms required national universities in each 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; this

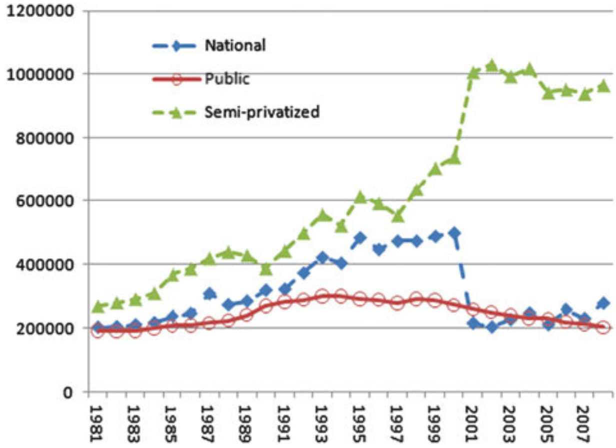

Fig. 1 R&D expenditure in national, public, semi-privatized research institutes in Japan (million JPY). Note: Many national research institutes were incorporated in 2001. "Public" indicates local public technology centers. Information was collected from the Ministry of Internal Affairs and Communications, "Science and Technology Survey"

market was initially dominated by local public technology centers, which were the primary source of knowledge for small local firms.

In these new circumstances, local public technology centers are required to establish their own strategy to function as part of a regional innovation system. This study aims to propose a model describing the characteristics of regional innovation systems, and, using a comprehensive dataset on local public technology centers, the study quantitatively examines whether technology centers' strategies match the characteristics of the regional innovation systems. Although much research has been conducted on university spillovers in Japan (Kneller 1999, 2007; Motohashi 2005), 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.

The remainder of the paper is organized as follows. Section 2 describes local public technology centers in Japan and their policy impact. Section 3 identifies key resource allocation strategies of local public technology centers. Section 4 models the characteristics of regional innovation systems. Section 5 predicts the relationships between the resource allocation strategies of technology centers and the characteristics of the regions where technology centers are located. Section 6 tests the predicted relationships by using a comprehensive dataset of local public technology centers and discusses the implications of the empirical analysis. Section 7 summarizes theoretical and methodological contributions of the study, and refers to issues for future research.

2 Local Public Technology Centers in Japan

Local public technology centers, administrated by the prefectural and municipal governments, play three roles in regional innovation systems. First, they provide small local firms with various technological services, such as the inspection of raw materials and final products, consultations to solve problems in production processes, and the organization of workshops to diffuse new technologies. Second, they conduct their own research, patent their inventions, and license their patents to small local firms. Third, they help small local firms collaborate so as to facilitate product development among them. I will discuss the key roles of technology centers in regional innovation systems in greater detail in Sect. 3.

Regional innovation policy as represented by local public technology centers has its roots in the 1880s, before the beginning of modern economic growth in Japan. Figure 2 illustrates the founding of local public technology centers by year and by technological field.[1] In the early days, local public technology centers were primarily established to support agriculture, the most important industry in pre-modern society. The development of the heavy industry after the 1910s was followed by the establishment of an increasing number of local public technology centers to provide technological support to the manufacturing industry. In the 1950s and 1960s, the remarkable economic recovery in postwar Japan led to serious environmental side effects, prompting the creation of local public technology centers for environmental science. Today, most prefectures have at least two types of local public technology centers, providing support in the areas of agriculture and manufacturing. Certain technology centers offer services in specific fields of manufacturing, such as ceramics and textiles. Other centers are engaged in research and technological assistance in the areas of industrial design and civil engineering.

This regional innovation policy, unique to Japan, received attention from the US government in the 1990s, since it was recognized for its significant contributions to the rapid economic growth of postwar Japan. Owing to serious concerns over the decreasing competitive advantage in the manufacturing industry, the US government benchmarked local public technology centers in its manufacturing extension partnership program, the regional innovation policy that was implemented in the 1990s (U.S. Congress 1990). Public technology transfer organizations, such as manufacturing extension centers, were established to improve the technological capabilities of small local firms (Shapira et al. 1995, 1996; Feller et al. 1996; Shapira 2001). Empirical studies on this policy find positive effects on the

[1] Information was collected from "Current Status of Local Public Technology Centers" by the Japan Association for the Promotion of Industrial Technology. The upsurge of manufacturing technology centers in the 1980s and 1990s was affected by frequent administrative reform in local authorities. All the reorganized technology centers are counted as newly established technology centers because of the difficulty in identifying centers during the complicated process of reorganization.

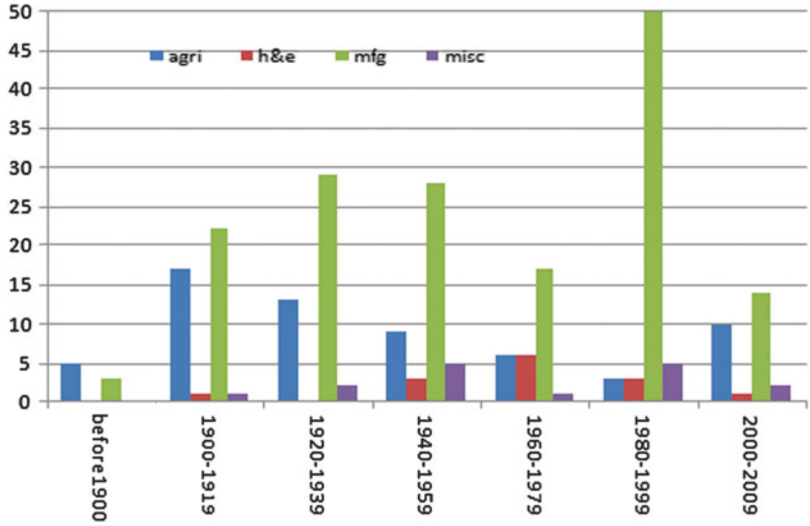

Fig. 2 The number of newly established local public technology centers by period and technology. Note *agri* agriculture, *h&e* public health and environmental science, *mfg* manufacturing, *misc* miscellaneous

productivity growth of program applicants (Luria and Wiarda 1996; Oldsman 1996; Dziczek et al. 1998; Jarmin 1999).

Although no econometric evaluation of the policy effects of local public technology transfer centers has been carried out to date, several studies suggest that local public technology centers contribute to the improvement of the technological capabilities of small local firms. Shapira (1992), based on interviews with center directors, reports that local public technology centers play an important role in improving product quality and in introducing new technology to small local firms. Comparing the manufacturing extension partnerships in the US with the local public technology centers in Japan, Ruth (2006) argues that the latter are superior to the former in terms of helping small local firms form interorganizational networks for innovation. Based on a questionnaire survey on networks among innovative small firms, Fukugawa (2006) finds that local public technology centers significantly contribute to the technological success of joint product development by such interfirm networks.

Others highlight the regional embeddedness of technology center scientists as an advantage of local public technology centers in the regional innovation system. The lifetime employment of technology center scientists encourages them to be involved in the regional economy and to establish stable and long-term relationships with small local firms, which in turn helps local public technology centers build mutual trust with customers. The job security of center scientists tends to result in the obsolescence of their technological knowledge. However, this is not detrimental to the technology transfer productivity of local public technology centers, because most of their customers typically do not engage in the development of state-of-the-art technology, and a small lag in knowledge diffusion does not affect the centers' ability to meet customers' needs for technological know-how (Shapira 1992; Hassink 1997).

3 Strategies of Local Public Technology Centers

As noted in Sect. 2, local public technology centers play three key roles in regional innovation systems: providing solutions to problems that small firms face in production processes; conducting their own research and licensing out the patented technology; and intermediating networks of innovative small firms. Although these roles are complementary to a certain extent, these activities compete for the limited resources of local public technology centers. In this sense, how intensively a technology center is engaged in a specific type of technology transfer represents a resource allocation strategy of the technology center. A comprehensive survey of local public technology centers, "Current Status of Local Public Technology Centers 2000–2009" by the Japan Association for the Promotion of Industrial Technology will be used here to analyze the resource allocation strategies of local public technology centers. Although this dataset provides information on local public technology centers in all technological categories, this study focuses on manufacturing technology centers. The definitions and descriptive statistics of variables are shown in Table 1. All variables are divided by the number of scientists to control for size of the centers.

Figure 3 shows the factor loadings computed by factor analysis. Factor analysis is a statistical method for extracting latent factors behind observable variables that affect several observable variables in the same direction. Given the screen plot, two factors with eigenvalues that are higher than one are extracted as the horizontal axis (Factor 1) and the vertical axis (Factor 2) in Fig. 3. Factor 1 strongly correlates with resource allocation variables that represent the proportion of Ph.D. scientists (*quality*), the number of papers published in academic journals per scientist (*paper*), the number of patents granted per scientist (*patgr*), and the number of patents applied for per scientist (*patap*); however, Factor 1 has no correlation with other variables.[2] The quality of human resources, research activities, and research outcomes are associated with the tendency of local public technology centers to intensify their research capacities. Factor 2 positively correlates with resource allocation variables that represent sharing information on new technologies (*workshop*), an open laboratory for the use of equipment that small firms cannot afford (*openl*), testing and inspection services (*test*), and providing small firms with

[2] Factor 1 also positively correlates with the number of research projects per scientist (*res*), but the correlation is not as strong as with other variables, probably because the variable reflects all types of research projects. Information on each type of research (e.g., funded research) is available for only a few empirical periods; therefore, factor analysis is difficult, since there are few observations to which it can be applied.

Table 1 Definitions and descriptive statistics of variables

Variables	Definition	N	Mean	S.D.	Min	Max
Quality	The proportion of Ph.D. scientists	902	0.20	0.15	0	0.9
Paper	The number of academic articles per scientist	828	0.20	0.32	0	7.6
Patgr	The number of patents granted per scientist	981	0.26	0.28	0	1.7
Patap	The number of patents applied for per scientist	975	0.52	0.59	0	8.3
Res	The number of research projects per scientist	998	0.64	0.29	0	1.7
Consult	The number of technological consulting services per scientist	956	105.50	108.60	0	822.5
Guide	The number of technological guidance services per scientist	879	24.93	40.47	0	289.3
Openl	The number of equipment rental services per scientist	926	75.62	189.15	0	4207.3
Test	The number of inspection and testing services per scientist	962	215.96	419.68	0	4193.5
Workshop	The number of workshops per scientist	973	2.12	5.27	0	117.1

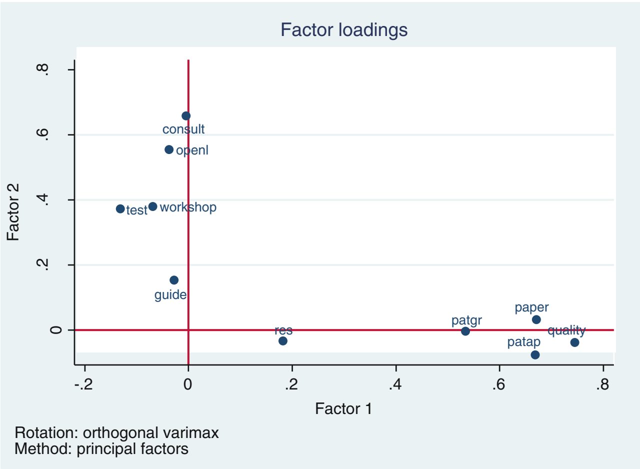

Fig. 3 Factor loadings

immediate solutions for technological problems (*consult* and *guide*); however, Factor 2 has no correlation with other variables. The variables correlated with Factor 2 are associated with the tendency of local public technology centers to disseminate technological knowledge to small firms.

Given these findings, Factors 1 and 2 are presumed to represent technology centers' resource allocation strategies for *knowledge creation* and *knowledge dissemination*, respectively. The correlation coefficient between Factor 1 and Factor 2 is very low (i.e., 0.02), implying that knowledge creation and knowledge dissemination are independent. Thus, it is difficult for local public technology centers to intensively pursue one type of strategy without giving up another type of strategy to some extent. Such a trade-off seems to be getting more serious, because most local authorities have experienced greater budget constraints since the 2000s (see Fig. 1), suggesting that efficient resource allocation to match regional environments is important.

4 Characteristics of Regional Innovation Systems

In order to identify the characteristics of regional innovation systems, this study assumes a local market for public technological services. Previous studies have suggested that demand and supply in a local market for public technological services determine how public knowledge is transferred to the private sector (Charles and Howells 1992; Santoro and Chakrabarti 2002; Schartinger et al. 2002; Carayol 2003). Specifically, the type of knowledge linkage established between industry and universities is determined both by demand-side factors, such as R&D intensity of local firms, and by supply-side factors, such as research quality of local universities. Given their arguments, this study assumes a local market for public technological services in which small firms seek and exploit public knowledge accumulated in the region, either to improve their production processes or to build long-term R&D capabilities.

The demand for public technological services in a region is affected by the attributes of small local firms. Although some regions have large firms, these firms are likely to have sufficient internal resources to solve technological problems independently. Furthermore, even if large firms encounter technological difficulties beyond their capabilities, they are unlikely to rely on regional public knowledge for solutions since they are likely to have developed global knowledge networks. The most important demand-side factor is the absorptive capacity of firms, that is, the ability to identify, understand, transform, and exploit external knowledge for their innovative activities (Cohen and Levinthal 1990; Zahra and George 2002). Absorptive capacity has a cumulative nature and is generated by R&D efforts of a firm, which makes it difficult for competitors to duplicate the resource immediately. Absorptive capacity affects how a firm interacts with a source of knowledge. Small firms relatively rich in absorptive capacity can employ an interactive channel of knowledge transfer, such as joint research, whereas small firms that do not perform R&D are likely to be supported by technology centers by means of a unilateral channel, such as technological consultation.[3]

[3] Absorptive capacity also affects the geographical range of knowledge interactions. Small firms with higher absorptive capacity may not rely on local public technology centers since they are likely to have developed global knowledge networks (Beise and Stahl 1999). Here, it is assumed that small local firms first seek a local market for technological services, and then expand their search for the next best option if the first trial fails.

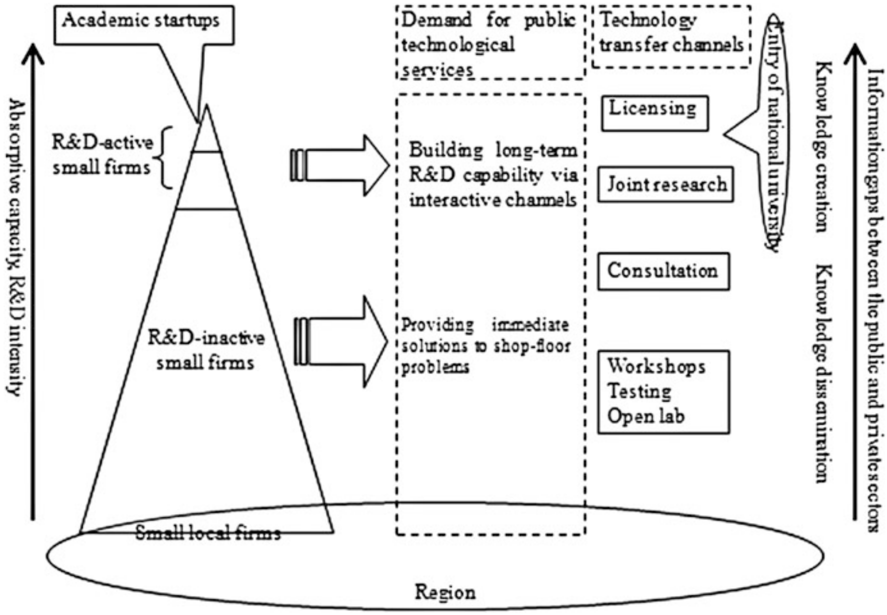

Fig. 4 Type of demand in a local market for public technological services

The supply of public technological services in a region is generated by national universities as well as local public technology centers. National research institutes may also contribute to the supply of public technological services. However, national research institutes in Japan are highly concentrated in Tokyo and Ibaraki prefecture (essentially in the city of Tsukuba), whereas at least one national university with faculties in the natural sciences is located in each prefecture. Furthermore, national research institutes engage in the R&D of state-of-the-art technology, which has little to do with the technological problems that are encountered by small local firms. If a national university in a particular region is relatively active in knowledge interactions with small local firms, it acts as a new entry into the local market for public technological services.

Given these arguments, the conceptual framework of regional innovation systems is illustrated in Fig. 4. The triangle on the left-hand side represents small local firms that demand public technological services. Area refers to the number of firms. The bottom of the triangle denotes small local manufacturers that do not engage in R&D, while the upper side denotes R&D-active small firms. The top of the triangle denotes small firms that devote themselves to research, such as academic startups. Small firms located in the upper portion of the triangle are assumed to have higher absorptive capacity, implying that they are likely to develop interactive and long-term relationships with external sources of knowledge. In contrast, small firms located at the bottom of the triangle demand public knowledge for immediate solutions to problems that occur at the shop-floor level, implying that the firms are likely to employ a unilateral channel of knowledge transfer.

The rectangles on the right-hand side represent the channels of knowledge transfer. Rectangles in the upper (lower) side refer to spillover channels with a relatively large (small) information gap between firms and external sources of knowledge (Izushi 2003, 2005). Information gaps are determined by the importance of communication between local public technology centers and small firms, and by the time required for small firms to evaluate the outcome of technological services. Izushi finds that the relationship between the two evolves over time. Small firms begin by using technological services with a smaller information gap, such as testing. After having developed mutual trust, small firms employ services with a larger information gap, such as joint research. Given these arguments, technology transfer channels are classified according to their information gap or the significance of the interactions.

The rectangles in the upper portion indicate that more interactive communication is needed when a larger information gap exists. In the case of joint research, scientists from both sides share their ideas, with matching research efforts, to create new knowledge. As shown in Fig. 3, the technology center's strategy, represented as Factor 1 (*knowledge creation*), is relevant for this kind of technology transfer. Furthermore, intellectual property licensing entails a larger information gap, which means that the licensing requires efficient communication or an efficient interface between open science and proprietary technology. When university patents are licensed to the private sector, gatekeepers with a deep understanding of science and business play an important role in evaluating the commercial potential of the invention and identifying a relevant industry partner who can commercialize the technology (Thursby and Thursby 2002). In contrast, rectangles in the lower portion indicate that hardly any communication is necessary between small firms and technology centers. In the case of technological consultation, the firm plays only a passive role, and knowledge is transferred unilaterally. The technology center's strategy, represented as Factor 2 (*knowledge dissemination*), is relevant for this kind of technology transfer. Furthermore, little interaction is necessary when local public technology centers either provide firms with testing services or let firms use their equipment.

5 Relationships Between Regional Innovation Policy and Regional Innovation Systems

In Sects. 3 and 4, I have introduced the methods by which regional innovation policy and regional innovation systems are measured. In this section, I will show how the fit between the two can be evaluated. Each prefecture is graphed in Fig. 5 according to the demand- and supply-side factors of a local market for public technological services. The vertical axis shows the proportion of small manufacturing firms in a prefecture that perform R&D. A high ratio implies that an average small manufacturer in the prefecture would have greater absorptive

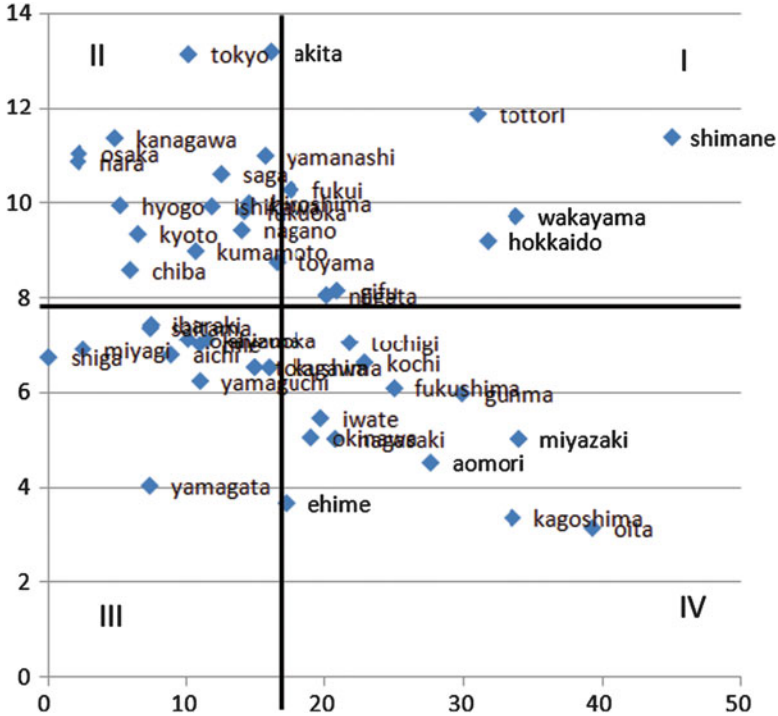

Fig. 5 Characteristics of regional innovation systems. Note (1) The vertical axis = the number of small manufacturers that perform R&D in a prefecture/sum of small manufacturers in a prefecture. See Sect. 4 for detailed definitions. The *horizontal line* denotes the average, approximately 8 %. The horizontal axis = the number of joint research projects between small local firms and national universities in a prefecture/sum of joint research projects conducted by national universities in a prefecture. The *vertical line* denotes the average, approximately 17 %. (2) Prefectures in Quadrant I are Fukui, Gifu, Hokkaido, Niigata, Shimane, Tottori, Wakayama. Prefectures in Quadrant II are Akita, Chiba, Fukuoka, Hiroshima, Hyogo, Ishikawa, Kanagawa, Kumamoto, Kyoto, Nagano, Nara, Osaka, Saga, Tokyo, Toyama, Yamanashi. Prefectures in Quadrant III are Aichi, Ibaraki, Kagawa, Mie, Miyagi, Okayama, Saitama, Shiga, Shizuoka, Tokushima, Yamagata, Yamaguchi. Prefectures in Quadrant IV are Aomori, Ehime, Fukushima, Gunma, Iwate, Kagoshima, Kochi, Miyazaki, Nagasaki, Oita, Okinawa, Tochigi

capacity. Information was collected from the Small- and Medium-sized Enterprise Agency, “SME Basic Survey 2008–2009.” Information on R&D prior to 2008 was not available from this survey. The horizontal axis shows the proportion of joint research projects between national universities and small firms in a region. The average of this ratio between 2000 and 2002 is used. Information was collected from the National Institute of Science and Technology Policy, “University-Industry Collaboration Database.” Since the incorporation of national universities in 2004, the universities have increasingly engaged in knowledge interactions with small local firms. When national universities in a region will be more eager to engage in joint research with small firms, small local firms will have greater opportunities to exploit university knowledge.

Figure 5 is divided into four parts by lines representing the averages of the horizontal and vertical axes.[4] Assuming that the characteristics of regional innovation systems are exogenous and invariant over time, and that regional innovation policy is dependent on them, the strategies of local public technology centers that match the characteristics of regional innovation systems are predicted as follows.

In Quadrant I, where the levels of both the demand and the supply variables are relatively high, there is a latent demand for high quality knowledge pool and interactive transfer channels in the region because of the presence of R&D-intensive small firms. Furthermore, a relatively high supply-side variable implies that knowledge created in national universities in the region is more accessible via joint research conducted with small local firms. It is reasonable to expect that in prefectures located in Quadrant I, small local firms that want to build long-term R&D capacity will exploit university knowledge in the region to a great extent. Therefore, in prefectures located in Quadrant I, local public technology centers need to distinguish themselves from the national university in the region by offering types of technological services that are different from those provided by the scientists of national universities. Therefore, in these regions, local public technology centers are expected to adopt a resource allocation strategy, represented as *knowledge dissemination*.

In Quadrant II, where the level of the demand variable is relatively high and the level of the supply variable is relatively low, a national university in the region is not willing to interact with small local firms despite their relatively higher R&D intensity. This mismatching between the demand for and supply of technological knowledge implies that in prefectures located in Quadrant II, local public technology centers should fill the gap by maintaining a higher technological capability, such as excellent scientists, and they should assist R&D-intensive small firms to innovate. In this case, knowledge transfer from public institutions to the private sector is expected to be interactive, because the small firms in Quadrant II are likely to have a higher absorptive capacity. Therefore, local public technology centers are expected to adopt a resource allocation strategy, represented as *knowledge creation*.

In Quadrants III and IV, where the level of the demand variable is relatively low, small local firms are likely to engage exclusively in production and distribution. Therefore, it is reasonable for local public technology centers located in a prefecture that is classified as being in Quadrants III or IV to adopt a resource allocation strategy, represented as *knowledge dissemination*. In such environments, local public technology centers are expected to offer technological services with a relatively smaller information gap, such as technological consultation and testing,

[4] The correlation coefficient between the demand- and supply-side variables is statistically insignificant; hence, the two axes can be depicted as orthogonal. Both variables are normally distributed, meaning that the average value can represent each variable.

Table 2 Predicted relationships between regional innovation policy and regional environment

Quadrant	Absorptive capacity of small firms	Accessibility of small firms to university knowledge in the region	Resource allocation strategy
I	High	High	Knowledge dissemination
II	High	Low	Knowledge creation
III	Low	Low	Knowledge dissemination
IV	Low	High	Knowledge dissemination

Note: See Fig. 5 for Quadrants I, II, III, and IV. See Sect. 3 for Factor 1 and Factor 2

since small local firms in the region tend to need local public technology centers for immediate problem solving in the production process rather than for building long-term R&D capability. Table 2 summarizes the theoretically predicted strategies (shown in column 4) of local public technology centers that match the characteristics of regional innovation systems (shown in columns 1, 2, and 3).

6 Results

Have local public technology centers allocated their resources to match the characteristics of regional innovation systems in the period when they were required to allocate resources more efficiently? The purpose of this section is to examine the statistical relationship between the characteristics of regional innovation systems and the theoretically predicted strategies (shown in Table 2) of local public technology centers. Specifically, I conducted an analysis of variance to examine whether the average of year-on-year growth (2000–2009) of each variable that represents a resource allocation strategy varies according to the characteristics of regional innovation systems as of 2000–2002, as represented by four quadrants in Fig. 5. A positive value for the average of year-on-year growth indicates that the local public technology center reinforced the resource, whereas a negative value indicates that the local public technology center relinquished the resource. As suggested by Table 2, Factor 1 (*knowledge creation*) should be reinforced in Quadrant II, whereas Factor 2 (*knowledge dissemination*) should be reinforced in Quadrants I, III, and IV. Therefore, resource allocation variables such as *workshop*, *consult*, *guide*, *openl*, and *testing* are predicted to exhibit significantly higher growth in Quadrants I, III, and IV, whereas resource allocation variables such as *quality*, *paper*, *res*, *patgr*, and *patap* are predicted to exhibit significantly higher growth in Quadrant II.

Table 3 shows the results of the analysis of variance. As summarized by Table 2, it was predicted that variables related to *knowledge creation* would show

Table 3 One-way analysis of variance

Strategy	Knowledge creation					Knowledge dissemination				
Variables	*Quality*	*Patgr*	*Patap*	*Paper*	*Res*	*Consult*	*Test*	*Openl*	*Workshop*	*Guide*
I	0.07	0.03	0.23	0.31	0.01	0.03	0.09	0.41	0.16	0.48
II	0.07	0.07	0.14	0.19	−0.002	0.08	0.20	0.81	0.26	0.92
III	0.13	0.12	0.18	0.24	0.01	0.29	0.20	0.20	0.07	1.48
IV	0.08	0.14	0.21	0.12	0.01	0.10	0.05	0.42	0.07	0.32
F value	1.44	0.93	0.59	0.50	0.17	3.37*	0.90	0.73	0.76	0.76

Note: Values in cells denote the average of year-on-year growth (2000–2009). Knowledge creation variables (*quality*, *patgr*, *patap*, *paper*, *res*) are expected to show higher growth in Quadrant II. Knowledge dissemination variables (*consult*, *test*, *openl*, *workshop*, *guide*) are expected to show higher growth in Quadrants I, III, and IV

*$p < 0.05$

significantly higher growth in Quadrant II, but variables related to *knowledge dissemination* would show significantly higher growth in the other quadrants. The results, however, show no significant difference across quadrants in most variables; that is, local public technology centers allocated their resources regardless of the characteristics of their regional environments. The only exception is technological consultation, which shows higher growth in Quadrants III and IV, as predicted in Table 2. Overall, the results suggest that small local firms lost an opportunity to improve their productivity by leveraging external knowledge, because of the misallocation of resources by the local public technology centers in the region. Specifically, small local firms might not have needed the types of technological services that were being provided by local public technological centers, but they were unable to find the services that they actually needed. Therefore, the resource allocation strategy of local public technology centers must be considered inefficient. In other words, economic welfare in a region would have improved if the local public technology centers had allocated resources according to the characteristics of their regional innovation systems.

The statistical analysis extracts the average look of local public technology centers from observations. However, an outlier sometimes gives important information when it represents a very distinctive example among the observations. Figure 6, which presents the factor scores, illustrates such distinctive strategies, that is, those of the Osaka Municipal Technical Research Institute, which pursues a strategy that intensifies its own research capability. The quality of its human resources is very high, which attracts external research funds via funded research, and these lead to higher research productivity, as represented by the number of papers and patents. Osaka prefecture is located in Quadrant II, where small local firms are relatively rich in absorptive capacity and where a national university in the region is relatively inactive in research collaborations with small local firms. Although Osaka has many R&D-intensive small firms, Osaka University, one of the leading research universities in Japan, develops knowledge networks across prefectures and the nation, and thus, it is less embedded in the regional economy. The model developed in this study suggests that it would be reasonable for the

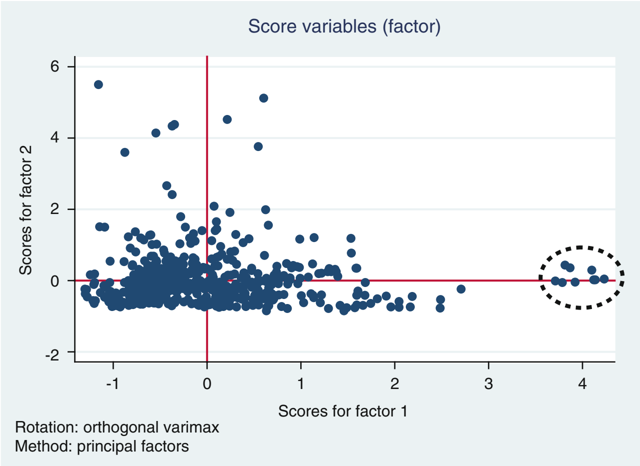

Fig. 6 Factor scores. Note *Dots* within the *circle* denote the Osaka Municipal Technical Research Institute

Osaka Municipal Technical Research Institute to intensify its research capacity, so that small local firms with absorptive capacity can rely on it. It is also rational that the Osaka Municipal Technical Research Institute was incorporated in 2008, which implied less administrative pressure from Osaka city and increased incentives to obtain external funds by exhibiting a high-quality research output by means of publications and patents. Figure 6 also shows that many technology centers are located around the origin. This implies that, since local public technology centers are expected to provide small local firms with a highly standardized list of technological services, it is generally difficult for each technology center to develop its own strategy to match the characteristics of regional environments.

7 Conclusion

This study contributes to the existing literature by introducing a new methodology for the quantitative evaluation of the effectiveness of regional innovation policies. I have developed a model to describe the characteristics of regional innovation systems. Thereafter, the relationships between regional innovation policies represented as resource allocation strategies of local public technology centers and the characteristics of the regions where technology centers were located were tested. There were no significant differences in the strategies adopted by local public technology centers, which corresponded to the characteristics of the regional innovation system. The case of a highly research-intensive technology center described in Sect. 6 (the Osaka Municipal Technical Research Institute) represents the complementary fits between regional policy and regional environment;

however, such cases seem exceptional. As shown in Sect. 2, previous literature has argued that local public technology centers have helped small local firms improve their technological capabilities. However, the results of this study imply that the resources of local public technology centers may not have been optimally utilized to facilitate regional economic development. In other words, local public technology centers might have provided small local firms with irrelevant technological services, and the small local firms might have faced difficulties in finding services that they actually needed. In order to redesign technology center's strategies so that they will match the characteristics of regional environments, the finer and more precise indicator which enables to identify the characteristics of regional innovation systems by technological category should be developed. My future research will incorporate a patent database to describe how small firms invest in R&D in specific technological fields.

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