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ASSESSING THE IMPACT OF SCIENCE PARKS ON KNOWLEDGE INTERACTION IN THE REGIONAL INNOVATION SYSTEM

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Abstract:
In the regional innovation system, science parks are expected to act as a catalyst for localized knowledge flow. Based on micro data on new technology-based firms (NTBFs) located in science parks and a questionnaire survey to science park managers, whether science parks are efficient and which science parks are more efficient are examined. Empirical results show that on-park NTBFs are unlikely to establish localized knowledge linkages, represented as joint research with universities and public research institutes. Furthermore, science parks that provide organizational arrangement, instead of the physical advantage, for R&D of tenants encourage knowledge interactions between tenants and universities.

JEL - codes: O, R, Z

Assessing the impact of science parks on knowledge interaction in the regional innovation system

Keywords

Science parks; regional innovation system; new technology-based firms; joint research

Abstract

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JEL: O33, M21, R58

1. Introduction

Science parks aim to promote the creation and growth of new technology-based firms (NTBFs) by facilitating localized knowledge flow represented as university-industry collaboration in the region. In Japan, the former half of the 1990s saw the advent of a science park boom, reflecting the bubble economy in the late 1980s and several regional development policies implemented in the 1980s. Most of the science parks are administrated by local authorities or public-funded joint ventures. Therefore, it is important to assess whether science parks contribute to facilitating knowledge flow in the regional innovation system. In Western countries, many empirical studies quantitatively evaluate the policy impact of science parks. They evaluate science parks from several perspectives, such as the promotion of localized knowledge flow, survival rate of tenants, growth in sales or employment of tenants, innovation output of tenants, the formation of R&D agglomeration in the region, and reputation of tenants. Many of the empirical studies assess science parks as enclaves of innovation where knowledge interaction with university-based scientists is scarcely observed, rather than seedbeds of innovation. One of the reasons is that R&D-inactive firms move into science parks simply because they are recognized as prestigious in the business community. Furthermore, science park managers lower standards in selecting tenants to secure rent income. In Japan, quantitative policy evaluation was scarce due to the absence of official definition and statistics on science parks. Therefore, most of the empirical studies on science parks have relied on case studies on successful science parks and tenants.[1]

To fill this gap, this study addresses two research agendas based on several statistical methods. (1) Based on micro data on NTBFs, whether science parks act as an efficient catalyst for localized knowledge flow is evaluated. (2) Based on a questionnaire survey for science park managers, which

[1] One exception is Fukugawa (2006) that employed micro data of NTBFs and estimated the impact of Japanese science parks on localized knowledge flow.

science parks are efficient in linking tenants with higher education institutes (HEIs) is examined. Foreshadowing the results, compared to off-park NTBFs, on-park NTBFs are not likely to collaborate with HEIs in research, nor do they tend to develop localized knowledge linkages with HEIs. The physical advantage of science parks such as geographical concentration does not contribute to facilitating localized knowledge flow. Rather, organizational arrangement for R&D of tenants is a more significant factor in encouraging knowledge interaction between tenants and university-based scientists. The remainder of this paper is organized as follows. Key concepts related to this study and provide information on Japanese science parks are defined in Section 2. In Section 3, I review previous empirical studies on value-added contributions of science parks to the regional innovation system.[2] The dataset for statistical analyses is described in Section 4. From the viewpoint of the promotion of localized knowledge flow, whether Japanese science parks are efficient is assessed in Section 5, and which science parks are more efficient in Section 6. In Section 7, implications of the results and agendas for further research are noted.

2. Definition of science parks

In Japan, different terms are employed by local authorities to indicate science parks. This stems from the absence of an official definition. Therefore, industrial parks, incubation centers, and science parks are identified based on three functional components: park, incubator, and HEI. Table 1 gives definitions of the three types of property-based initiative according to the configurations of these components. 'Park' refers to the development of a property that enables NTBFs to engage in R&D and that enables R&D-related facilities to be located in the vicinity. 'Incubator' refers to a facility for business services for those who aim to start or have established NTBFs, while it does not refer to a large-scale property

[2] The term "value-added" is widely used by both academics and practitioners engaged in business incubation (Mian, 1996, p325.). It corresponds to the provision of the business, technical, and social infrastructure to support the development of NTBFs.

development required for an industrial park. 'HEI' refers to a site location of research facilities or liaison offices of HEIs or the presence of a partnership with HEIs. Table 1 indicates that science parks should provide tenants with opportunities for knowledge transfer from local HEIs, while they do not necessarily offer tenants business services regarding financial or marketing problems. In contrast, incubation centers organize human resources that augment the managerial skills of NTBFs, while these facilities are not supposed to help NTBFs establish a linkage with HEIs. Finally, industrial parks provide their tenants with neither business services nor geographical advantages in developing HEI linkages.

Table 1 here

Here, an overview on Japanese science parks is provided based on a survey by the Tokyo Institute of Technology (TIT) which employs a definition of science parks that differs from that used in this study. Figure 1 shows the distribution of the year of operation of science parks including those scheduled for construction. TIT (1998) identified 158 science parks in Japan in 1997. Figure 1 indicates that many Japanese science parks began to operate in the bubble era in the late 1980s and started to operate in the early 1990s. This boom reflects the policies on national land development that were implemented from the late 1980s to the early 1990s.[3] As a whole, these policies aimed to reallocate industries that create higher value-added from big cities to rural areas and to develop agglomerations of such businesses in the regions. One of the most influential policy schemes was the "Law on the promotion of agglomerations of specific

[3] Several policy schemes affected the science park boom in Japan. They include the "Law on the promotion of Technopolis" enacted in 1983, "Law on the utilization of capability of the private sector" enacted in 1986, "Law on decentralization in national land development" enacted in 1988, and "Law on the promotion of the nodal city in the region and reallocation of industry" enacted in 1992.

businesses that intensify the knowledge-based regional economy" enacted in 1988.[4] Specific businesses refer to knowledge-creating activities such as R&D. Since specific businesses had heavily concentrated in Tokyo, the policy was intended to balance the location of agglomerations of specific businesses in the nation. Based on this scheme, 26 regions were approved to promote the agglomerations of specific businesses based on property-based initiatives such as science parks. Other relevant policies also appointed several regions to develop agglomerations of R&D-related activities. As a result, 65% of Japanese science parks were appointed by at least one policy on national land development. Over 80% of the science parks were planned either by the local authority or by a joint public-private venture.

Figure 1 here

3. The previous literature

Table 2 shows the results of the literature review in the relevant field of research.[5] Several types of value-added contribution of science parks to NTBFs located in science parks (on-park NTBFs) were investigated by previous empirical studies, including survival and growth, establishment of HEI linkage, innovation output, reputation, and the formation of R&D agglomeration. Among the value-added contributions of science parks addressed by the previous studies, this study focuses on whether science parks act as a catalyst for localized knowledge flow from an HEI to on-park NTBFs. This is because the science parks as defined in the previous section are supposed to provide tenants with geographical or organizational advantages in developing networks to local HEIs.

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[4] Although this law was abolished in 1998, its policy framework was inherited by the "Law on the promotion of creating new businesses" that was abolished in 2005.

[5] For a review of the empirical literature on assessment of science parks, see Siegel et al. (2003a) and Phan et al. (2005).

Table 2 here

According to Table 2, several studies find no significant correlation between science park location and tenants' establishing HEI linkages. Science parks in some countries help on-park NTBFs develop an HEI linkage while the channel of knowledge transfer employed is unidentifiable from the studies (Colombo and Delmastro, 2002; Lofsten and Lindelof, 2002). However, many studies show that the linkage tends to be informal (Vedovello, 1997; Phillimore, 1999) and characterized by a low level of interaction, such as the use of university facilities (Felsenstein, 1994; Westhead and Storey, 1994).[6] The level of HEI interaction by tenants is lower than expected because science park managers lower their standards in selecting tenants to secure rent income, and R&D-inactive firms choose science parks simply because they are prestigious in the business community (Van Dierdonck et al., 1991; Felsenstein, 1994; Westhead and Storey, 1994). Such a low level of knowledge interaction between on-park NTBFs and local HEIs suggests a low level of the spillover that is prerequisite for R&D agglomeration. Examining science parks in the US, Appold (2004) argues that science parks do not contribute to the formation of R&D agglomeration in the region of interest. On the contrary, science parks are located where a high level of technological opportunities, represented by research laboratories of the private sector, is provided. Furthermore, regarding the innovation output of on-park NTBFs, most of the empirical literature does not support the view that science parks encourage on-park NTBFs to yield more R&D output (Westhead and Storey, 1994; Westhead, 1997; Colombo and Delmastro, 2002; Lindelof and Lofsten, 2003).[7] Even if

[6] Lindelof and Lofsten (2004) indicate that Swedish science parks encourage both formal and informal research networks between on-park NTBFs and a local university, including joint research, consultation, and discussion.

[7] Most of the empirical studies employ matched-pair analysis as the empirical method. Based on an alternative empirical method,

science parks do promote the introduction of radical innovations by NTBFs in the market, this effect is contingent on entrepreneur-specific factors such as work experience in the R&D department (Felsenstein, 1994).

In summary, the previous empirical literature does not present a favorable view of science parks as seedbeds for innovation. Rather, they indicate that science parks tend to function as enclaves of innovation (Felsenstein, 1994) wherein HEI linkage via highly interactive channels is hardly developed, and the innovation output and firm growth observed may stem from spurious correlation with other influential factors. As stated above, this may reflect adverse selection regarding science park managers' choosing potential tenants.[8] In other words, undesirable users could reduce the estimated value-added contributions of science parks. Assuming R&D-active firms as potential tenants of Japanese science parks,[9] on-park NTBFs, other things being equal, are predicted to establish localized knowledge linkages via an interactive channel, represented as joint research with HEI-based scientists.

4. Data

To address the two research agendas introduced in Section 1, two types of dataset are used: micro data on new technology-based firms (NTBFs) located in science parks and questionnaire survey to science park managers.

Siegel et al. (2003b) show that on-park NTBFs exhibit higher research productivity than off-park NTBFs.

[8] Critical views on the innovation policy on which British science parks are based argue that since the modern innovation process is complex, the linear model of the innovation, represented as the isolation of R&D, disrupts the feedback loop from the other phases and thus is undesirable for the promotion of knowledge flow and innovation (MacDonald, 1987; Massey et al., 1992; Quintas et al., 1992).

[9] This assumption reflects constraints in creating the empirical sample. Since I could not identify the population of on-park NTBFs due to the lack of official data, I had to rely on the database of small R&D-active firms, as noted in Section 4.

Since there is no administrative organization for science parks in Japan, it is difficult to identify the population of on-park NTBFs. Therefore, Nihon Keizai Shinbunsha "Nikkei Annual Corporation Reports of Venture Business (NVB)" from 2001 to 2003 is used. NVB is an annual survey that collects information on approximately 2500 small firms that it identifies as NTBFs. NVB defines NTBFs as firms with characteristics such as (a) unlisted or non-over-the-counter share market firms, (b) technology-based firms, (c) high growth firms, and (d) young firms or new entrants. NVB provides information on with whom NTBFs cooperate in research, which is used as the indicator of (localized) knowledge interactions with HEIs. To identify the types of property-based initiatives that NTBFs locate, the Japan Association of New Business Incubation Organization "Business Incubation Directory (BID)" in 2003 is employed. The BID provides information on property-based initiatives, including science parks and incubation centers. The procedure for creating the dataset is as follows. First, using the BID, the type of property-based initiative that houses an NVB-listed NTBF is identified. Second, the treatment group and the control group are generated. The treatment group refers to on-park NTBFs. The control group refers to NTBFs not located in science parks, while otherwise similar to the treatment group. The control group is matched against the treatment group with respect to industry, location, age of the firm, and ownership structure. These factors are widely used in empirical studies based on matched-pair analysis (Westhead and Storey, 1994; Colombo and Delmastro, 2002; Lofsten and Lindelof, 2002). The industrial classification defined by NVB is approximately equivalent to the two-digit standard industrial classification. The location is measured at the prefectural level. The ownership structure is matched so that both on-park and off-park NTBFs are both owner-managed businesses. As a result, an unbalanced panel that consists of 3 periods, 37 on-park NTBFs, 37 off-park NTBFs, and 140 observations was obtained. On-park NTBFs are located in 15 science parks and Table 3 shows their geographical distribution.[10]

[10] 14 of the 15 science parks that have appeared in our sample house HEIs within the park. Of these, the one science park that does not

Table 3 here

In order to address the second research agenda, micro data from a questionnaire survey to managers of property-based initiatives including science parks are used. The National Institute of Science and Technology Policy (NISTEP) conducted a nationwide survey during 1993 and 1994 and disclosed a good part of the micro data in NISTEP (1996). They sent a questionnaire to 137 managers of property-based initiatives. NISTEP classifies the 111 respondents into three groups: 29 innovation centers; 46 R&D parks; and 36 science parks. Among these groups, science parks and R&D parks are identical to the 'science park' in Table 1, since all respondents have HEIs located on the site. Innovation centers and science parks are supposed to arrange facilities for incubation business while R&D parks are not. Science parks, most of the innovation centers, and half of the R&D parks offer tenants facilities for mobilization, information exchange, and the training of tenant scientists. NISTEP refers to this facility as a 'communication center,' which is predicted to encourage knowledge interactions between tenants and HEIs.

5. Are science parks efficient?

Many of the previous studies evaluating the policy effect of science parks employ matched-pair analysis as the empirical method. This approach conducts the test of difference between the treatment group and control groups. Table 4 indicates that although the treatment group is more likely to engage in joint research with HEIs than control group studies, the geographical range of knowledge interaction is not

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house an HEI within the park has established a partnership with an HEI in the vicinity.

localized. In addition, Table 4 shows that matching is unsuccessful regarding firm age.[11]

Table 4 here

However, it is notable that matched-pair analysis has several methodological flaws. Among them, how to deal with endogeneity is of great importance. Most of the previous studies based on this approach match the treatment group to the control group with regard to static factors such as location and industry but do not control for the dynamic characteristics of firms. Therefore, when firms with higher research potential tend to move into science parks, or policymakers place a high value on the dynamic aspects of firms, such as growth potential, in selecting tenants, it is inappropriate to assess the policy impact based on a matched-pair approach. In other words, when the adoption of science park policy is significantly correlated with factors that the previous matched-pair approach had not controlled for, it is impossible to identify from the results of matched-pair analyses whether the performance of tenants is attributable to science parks or firm-specific factors. Since science park location is not a random variable rationed by policymakers, but a selection variable of the firm, it is likely that the endogeneity problem takes place in policy evaluation regarding science parks.[12]

Therefore, in order to estimate the impact of science parks on the promotion of localized knowledge flow, a bivariate probit model that takes account of endogeneity is employed.[13] All of the

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[11] Table 4 shows the results on several value-added contributions of science parks on which this study does not focus. They include growth, innovation, and reputation of on-park NTBFs. Interpretation of the results is available from the author upon request.

[12] Colombo and Delmastro (2002) argue that this type of sample selection bias could be cancelled out since poorly performing firms are also likely to call for protection provided by the policy scheme.

[13] For details of a bivariate probit model, see Maddala (1983; 117-125) and Greene (2000; 849-856). They refer to this model as a

parameters are estimated based on the first equation and the second equation. The second equation is:

$$D1 = aD2 + bX + e1 \qquad (1)$$

where D1 is a binary dummy representing knowledge interaction with HEIs, D2 is a binary dummy representing science park location, and X is the determinants in knowledge interaction with HEIs other than science park location. The first equation is:

$$D2 = cY + e2 \qquad (2)$$

where Y is the determining factors in firms' locating in science parks and cov[e1, e2] = rho. The statistical significance of rho denotes that unobservable factors in the decision on science park location affect the value-added contributions of science parks to NTBFs, indicating the presence of endogeneity.

Proxy variables of research capacity and firm growth are introduced as determinants in science park location. Since matching is unsuccessful regarding firm age, firm age is introduced to the regression models. Here, a proxy variable for firm growth is included in the first equation but not in the second equation. This is an instrumental variable that acts as condition for parameter identification. In other words, policymaker may select tenants according to dynamic measures such as sales growth from the previous period to the present period. Simultaneously, this measure is considered to be uncorrelated with unobservable determinants in joint research with HEIs such as the long-term research plan of the entrepreneur. Age of the firm and research capacity as determinants in joint research are introduced. To control for the variation of technical opportunities across industries and regions, R&D intensity at the industry level and the number of HEIs in the prefecture is introduced. The information of the former is collected from the Ministry of Economy, Trade, and Industry, "Basic Survey of Japanese Business Structure and Activities" in 2001. The information of the latter is collected from the Ministry of Education,

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recursive bivariate probit model. For empirical applications of this model, see Burnett (1997), Greene (1998), and Knapp and Seaks (1998).

Culture, Sports, Science, and Technology, “Basic Survey of Higher Education Institutions” in 1998. Since I created the sample based on matched-pairs, the science park location dummy has already been incorporated with other factors, such as industry and location. Therefore, control variables to the science park location equation are introduced. The coefficient of the science park location dummy based on this regression model denotes the science park effect that adjusts for endogeneity regarding policy application.

Table 5 shows the results of regression analyses. Model 1 indicates that, after controlling for endogeneity, there is no significant difference between the treatment group and the control group is found regarding the possibility of collaboration in research with HEIs. It is reasonable that NTBFs with higher research capacity tend to engage in joint research with HEIs since R&D intensity captures absorptive capacity (Cohen and Levinthal, 1990) that is required when firms employ a more interactive channel of knowledge transfer such as joint research. Furthermore, coefficients of the science park location dummy become significant and negative in Models 2, 3, and 4, indicating that on-park NTBFs are less likely to conduct joint research with HEIs than on-park NTBFs. In the localized knowledge interaction equation, control variables representing industry, regional, and time effect enter into regression models alternatively since introducing them simultaneously yields difficulty in computation. Model 5 provides no support for the view that on-park NTBFs are more likely to establish localized knowledge linkages with HEIs than off-park NTBFs. Furthermore, Models 6 and 7 show that being on-park NTBFs is disadvantageous when they establish localized knowledge interaction with HEIs, which clearly contradicts our prediction. Models 5, 6, and 7 show that older NTBFs are likely to engage in joint research with local HEIs. The research capacity of the firm is not an influential factor in establishing localized knowledge interactions as it is in the knowledge interaction equation. Models 5, 6, and 7 indicate that NTBFs with higher growth tend to move into science parks, suggesting that policymakers place a high value on dynamic factors in selecting tenants, or managers wish to establish HEI linkages for greater growth. Lastly, rho, the correlation between error terms, shows insignificant results except for Model 7, indicating that science park location is randomly rationed among NTBFs. This problem is left for the future research.

Why then are science parks inefficient (even deterrent) as a catalyst for localized knowledge flow? Several factors concerning tenants, HEIs, and science parks might be behind the empirical findings. First, on-park NTBFs may exploit university knowledge via channels of knowledge transfer other than joint research. Since no information on other channels employed by on-park NTBFs is available, I cannot provide conclusive argument for this point. However, the physical advantage offered by science parks can be conducive to the transfer of codified knowledge via a less interactive channel such as licensing. Jensen and Thursby (2001) argue that since university invention tends to be embryonic and contains systemic knowledge of academic inventors, the post-licensing involvement of academic inventors is necessary for successful development of the technology, and licensing contracts should be designed so that academic inventors exert effort for post-licensing collaboration.[14] Second, universities located in science parks do not sufficiently motivate faculty members to interact with local firms. Recent empirical studies show that an incentive mechanism designed for transfer agents, including university-based scientists, is influential in the efficiency of university-industry knowledge transfer (Thursby and Kemp, 2002; Siegel et al., 2003; Markman et al., 2004). However, it is difficult to control for the interuniversity variation in the scientists' motivation for university-industry collaboration. Third, even if science parks provide tenants with a physical advantage in localized spillover, they lack organizational capacity in linking tenants and HEIs effectively. Zucker and Darby (2001), examining the Japanese biotechnology industry, show that the proximity to universities does not necessarily improve knowledge transfer that promotes industrial

[14] A forthcoming paper by Agrawal shows that post-licensing interaction between the academic inventor and the licensee is critical for the successful development and commercialization of university inventions. However, the study provides no evidence that the geographical proximity plays a significant role in achieving the successful development and commercialization of university inventions.

innovation. In other words, if organizational or institutional factors prevent university-based scientists from interacting with the private sector, as was the case in Japan, it is reasonable that little evidence of localized knowledge spillover is observed. The results suggest the possibility that Japanese science parks lack the organizational framework to efficiently connect NTBFs and public knowledge within the park, while they do arrange physical infrastructure for university-industry collaboration.

Table 5 here

6. Which science parks are more efficient?

Most of the empirical studies evaluating science parks, including the analysis in the previous section, compare the treatment group to the control group focusing on a specific criterion of policy impact. Reviewing the trend in science park studies, Siegel et al. (2003a) point out science park heterogeneity as a promising research frontier. In other words, it is important to investigate not only whether science parks are efficient, but also which type of science park is more efficient. Provided the promotion of localized knowledge flow is the appropriate performance measure of science parks, which factor is influential in the variation of performance of science parks? In order to address this empirical agenda, it is necessary to arrange a qualitative dataset on science parks. In the questionnaire survey described in Section 4, NISTEP asks managers of property-based initiatives how frequently tenant scientists and local HEIs interact in research. Specifically, the degree of interaction between tenants and local universities, public research institutes, and national research institutes is coded as frequently=1, often=2, occasionally=3, and seldom=4. Taking an average of three types of HEIs, I create the indicator of interaction with HEI-based scientists. Using these dependent variables, which science parks are likely to contribute to facilitating knowledge interaction among tenant scientists and HEIs is examined. An ordered probit model is applied to the former dependent variable and ordinary least squares (OLS) is applied to the latter dependent variable.

Independent variables are as follows. Binary dummies taking a value of one when the property-based initiative arranges for incubation-related facilities or communication centers, and zero otherwise are used. In addition, the questionnaire asks science park managers how they help tenants engage in innovative activities. Binary dummies taking a value of one when the property-based initiative provides tenants with R&D services regarding human resources, physical resources, financial resources, and technical resources, and zero otherwise are used. Lastly, size and age of science parks and regional characteristics are controlled for.

Table 6 shows the results of the regression analyses. All models show that arranging facilities for mobilization, information exchange, and the training of scientists has insignificant impact on promoting knowledge interaction. On the contrary, science parks providing R&D services regarding human resources make a significant contribution to the promotion of knowledge interaction. These findings are consistent with the results in Table 5 in that the physical advantage of science parks, represented as geographical concentration, does not lead tenants to establish localized knowledge interactions. Rather, science park heterogeneity in R&D services regarding human resources, such as intermediation of qualified scientists and engineers, has a greater explanation power for variation in the performance of science parks. This implies that science parks that act as liaison in the research community promote knowledge interaction between tenants and HEIs. Empirical studies on British science parks indicate that science parks managed by a gatekeeper who retains many contacts inside and outside the science park offer tenants greater opportunities to survive by exploiting these networks (Westhead and Storey, 1994; Westhead and Batstone, 1999).[15] Similarly, empirical findings suggest that science parks can be a more efficient catalyst through

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[15] Cohen and Levinthal (1990) describe the gatekeeper as the human resource that possesses the ‘knowledge of who knows what, who can help with what problem, or who can exploit new information’ (Cohen and Levinthal, 1990: 133). In a similar context, Santoro and Chakrabarti (2002) find the champion (Chakrabarti, 1974) playing a key role in establishing university-industry relations in the

developing human resources, as well as property development, acting as an interface between different norms, i.e., open science and proprietary technology.

Table 6 here

7. Conclusion

In the regional innovation system, science parks are expected to act as a catalyst for localized knowledge flow. It is, however, often difficult to assess the science park effect due to the unavailability of the micro dataset and methodological problems. Using micro data on NTBFs located in science parks and a questionnaire survey to science park managers, this study addresses two research questions: (1) whether science parks act as an efficient catalyst; and (2) which science parks are more efficient. Based on regression analyses, it is shown that on-park NTBFs are unlikely to establish localized knowledge linkages represented as joint research with local HEIs. Furthermore, science parks providing tenants with R&D services regarding human resources facilitate localized knowledge flow while those arranging facilities for communication among scientists of tenants and HEIs do not. The results suggest that human resource development, as well as property development, acting as an interface between HEIs and NTBFs is the key for science parks to encourage localized knowledge interactions. This is consonant with the recent focus of regional innovation policy on human resource development in Japan. Since 2002, the Ministry of Education, Culture, Sports, Science and Technology has deployed university-industry coordinators at the liaison offices of national universities. The Japan Association of New Business Incubation Organization (JANBO) has implemented training programs for incubation managers since 1999. According to JANBO (2003), incubation managers are expected not only to be advisors who provide entrepreneurs with

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solutions to managerial problems, but also to be coordinators who link entrepreneurs with the source of knowledge that resides outside the facility. The skill of such human resources greatly varies according to their work experience and social capital such as laboratory and cosmopolitan networks (Murray, 2004). Therefore, in order to derive more detailed policy implications, it is necessary to arrange the dataset on heterogeneity of such human resources and investigate which types of skills are more important for the creation and development of university-industry collaborations in the region.

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Table 1 Definitions for three types of property-based initiatives

	Park	Incubator	HEI
Industrial park (IP)	Yes	No	No
Incubation center (IC)	No	Yes	No
Science park (SP)	Yes	Yes / No	Yes

1. 'Park' refers to the development of a property that enables new technology-based firms to engage in R&D and enables related facilities to locate in close vicinity.
2. 'Incubator' refers to a facility for business services for those who aim to start or have established new technology-based firms.
3. 'HEI' refers to a site location of research facilities or liaison offices of higher education institutes or the presence of a partnership with higher education institutions.

Table 2 Review of empirical studies on value-added contributions of science parks

	Unit of analysis	Method	Period	Region	Sample	Results
Monck et al., 1988	Firm	Matched-pair	1986	UK	183-101	G, H
Van Dierdonck et al., 1991	Science park	Descriptive	1988	Belgium, Netherlands	68(B), 71(N)	H
Felsenstein, 1994	Firm	Log-linear	Unknown	Israel	73-89	I(+), H(+)
Westhead and Storey, 1994	Firm	Matched-pair	1986, 1992	UK	75-62	S, G(+), I, H(+)
Westhead and Storey, 1995	Firm	Matched-pair	1986, 1992	UK	75-62	S(+), H(+)
NISTEP, 1996	Science park	Descriptive	1994	Japan	111	H
Vedovello, 1997	Science park	Case study	1993	UK	1	H(+)
Westhead, 1997	Firm	Matched-pair	1986, 1992	UK	75-62	S, I
Phillimore, 1999	Science park	Case study	1998	Australia	1	H(+)
Lofsten and Lindelof, 2001	Firm	OLS	1994-1996	Sweden	163-100	G(+)
Lofsten and Lindelof, 2002	Firm	Matched-pair, OLS	1999	Sweden	134-139	G(+), H(+)
Colombo and Delmastro, 2002	Firm	Matched-pair, Tobit	2000	Italy	45-45	G(+), I, H(+), R(+)
Lindelof and Lofsten, 2003	Firm	Matched-pair	1999	Sweden	134-139	I
Link and Scott, 2003	University	Ordered probit	2001	US	28	I(+), R(-)
Siegel et al., 2003b	Firm	Stochastic Frontier Estimation	1992	UK	89-88	I(+)
Appold, 2004	County	Switching regression	1960-1985	US	3024	A
Ferguson and Olofsson, 2004	Firm	Matched-pair	1995, 2002	Sweden	30-36	S(+), G
Lindelof and Lofsten, 2004	Firm	Matched-pair	1999	Sweden	134-139	I(+), H(+)

1. Sample for matched-pair analysis denotes the number of observations of the treatment and control sample, respectively.

2. S: survival; G: growth; H: HEI linkage; I: innovation; R: reputation; and A: agglomeration. Signs in parentheses denote positive or negative effects of science parks, if any, on each output measure.

Table 3 Geographical distribution of the science parks appeared in the sample and population

Region	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku-Shikoku	Kyushu-Okinawa
Sample	1	0	2	3	2	1	6
The population surveyed by TIT(1998)	8	10	31	19	19	11	16

1. Chi-square statistics=7.857, d.f.=6, p=0.248.

Table 4 Results of matched-pair analysis

	Method	Treatment	Control	Significance
Log(years from the establishment of the firm)	t-test	2.61	2.94	***
Joint research with HEIs=1, otherwise=0	Chi-square test	58%	32%	***
Research partners of the joint research-active NTBF include HEIs in the same prefecture=1, otherwise=0	Chi-square test	88%	72%	
Employment growth from the previous period to the present period	t-test	0.08	-0.02	*
Sales growth from the previous period to the present period	t-test	0.284	0.119	
Log(the number of patents granted to the firm)	t-test	0.507	0.375	
Log(the ratio of R&D expenditure to sales of the firm)	t-test	-2.88	-3.46	*
Financing from venture capital=1, otherwise=0	Chi-square test	27%	13%	*
Obtaining subsidy=1, otherwise=0	Chi-square test	36%	38%	
Manager’s wishing initial public offering in the future=1, otherwise=0	Chi-square test	78%	64%	

1. *** p<0.01, ** p<0.05, * p<0.1.
2. For several continuous variables, log transformation is required to satisfy the assumption of parametric test.

Table 5 Estimated bivariate probit models

Model	1		2		3		4	
Log likelihood	-85.831		-87.919		-86.661		-87.187	
N	71		71		71		71	
	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Knowledge interaction equation (Dependent variable: Joint research with HEIs=1, otherwise=0)								
On-park NTBFs=1, off-park NTBFs=0	-0.870		-1.183	***	-0.990	**	-0.949	***
Log(years from the establishment of the firm)	0.245		0.089		0.214		0.119	
The ratio of R&D expenditure to sales of the firm	3.729	**	2.625	**	3.582	**	2.796	**
The ratio of R&D expenditure to sales at the industry level(%)	0.023		-0.064					
Log(the number of universities and public research institutes in the prefecture)	0.579				0.960			
Empirical year	0.193						0.015	
Constant	-3.712		-0.035		-2.919		-2.851	
Science park location equation (Dependent variable: On-park NTBFs=1, off-park NTBFs=0)								
Log(years from the establishment of the firm)	-0.097		-0.087		-0.095		-0.085	
The ratio of R&D expenditure to sales of the firm	1.110		1.179		1.115		1.147	
Sales growth from the previous period to the present period	0.217		0.840		0.206		0.213	
Constant	-0.066		-0.510		-0.403		-0.456	
Rho	0.833		0.999		0.898		0.932	

1. *** p<0.01, ** p<0.05, * p<0.1.

Table 5 (continued)

Model	5		6		7	
Log likelihood	-20.655		-25.473		-25.561	
N	31		31		31	
	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Localized knowledge interaction equation (Dependent variable: Research partners of the joint research-active NTBF include HEIs in the same prefecture=1, otherwise=0)						
On-park NTBFs=1, off-park NTBFs=0	-0.556		-1.220	*	-1.234	**
Log(years from the establishment of the firm)	1.710	**	1.742	*	1.603	**
The ratio of R&D expenditure to sales of the firm	1.840		4.419		6.100	
The ratio of R&D expenditure to sales at the industry level(%)	-0.498					
Log(the number of universities and public research institutes in the prefecture)			-1.171			
Empirical year					-0.386	***
Constant	-1.877		0.902		0.461	
Science park location equation (Dependent variable: On-park NTBFs=1, off-park NTBFs=0)						
Log(years from the establishment of the firm)	0.117		0.113		0.131	
The ratio of R&D expenditure to sales of the firm	1.191		1.161		1.162	
Sales growth from the previous period to the present period	1.345	*	1.327	*	1.303	*
Constant	-0.523		-0.494		-0.569	
Rho	1		1		1	*

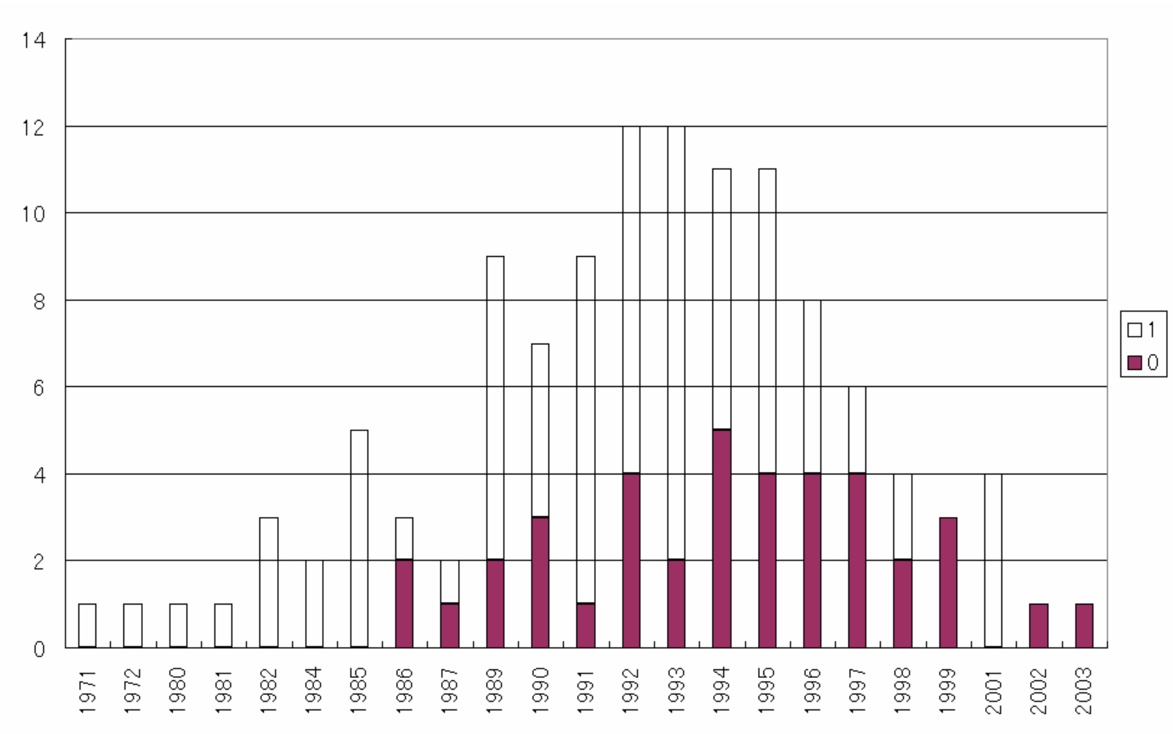
1. *** p<0.01, ** p<0.05, * p<0.1.
2. Control variables regarding region, industry, and time enter into regression models alternatively since introducing them simultaneously yields difficulty in computation.

Table 6 Estimated regression models

Model	1		2		3		4	
Method	OLS		OLS		Ordered probit		Ordered probit	
Adjusted R^2	0.346		0.401					
Log likelihood					-28.806		-30.999	
N	41		41		37		37	
	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Log(lot area)	-0.142		-0.163	*	-0.383	*	-0.312	*
Log(years from the establishment)	-0.032		-0.031		-0.154		-0.126	
Log(the population of the region)	-0.157		-0.264	**	-0.892	***	-1.127	***
Facility: The presence of incubator=1, otherwise=0	-0.189		-0.352		0.762		-0.404	
Facility: The presence of research communication center=1, otherwise=0	0.068		0.096		0.481		-0.425	
Support for R&D of tenants: human	-1.442	***	-1.595	***	-2.229	***	-2.595	***
Support for R&D of tenants: space	-0.318				-0.424			
Support for R&D of tenants: equipment	0.056				-1.337			
Support for R&D of tenants: capital	-0.203				-0.896			
Support for R&D of tenants: technical information	-0.114				-0.238			
Constant	0.846		-7.138					

1. Dependent variable of Models 1 and 2: Average of the degree of interaction with universities, public research institutes, and national research institutes
2. Dependent variable of Models 3 and 4: The degree of interaction between tenants and university-based scientists coded as: frequently=1; often=2; occasionally=3; and seldom=4
3. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Figure 1 Distribution of the year of operation of the Japanese science parks by HEI linkage



1. Author's elaboration based on Tokyo Institute of Technology (1998). Several observations represent the scheduled year of operation.
2. Science parks in the sample are coded "1" when the science park either houses research facilities or liaison offices of higher education institutions (HEIs) in the park or is in partnership with HEIs, and "0" otherwise.